Coding

Publication/Creation

1950-1954

Persistent URL

https://wellcomecollection.org/works/aadzc9q7

Set of elements

AAAB	AABA	ABAA		
AAAC	AACA	ACAA	ACCC	
AAAD	AADA	ADAA		
AABB	ABBA			
AABD	ABDA			
AADB	ADBA			
AADD	ADDA			
AABC	ABCA		ADCC	I.
AADC	ADCA		ABCC	
AACB	ACBA		ACCD	II
AACD	ACDA		ACCB	
ABAD	ADAB			III
ABAC	ACAB	ACDC		
ADAC	ACAD	ACBC		
ABCD	ADCB			IV
ABCB	ADCD			
ABBC	ADDC			
ACBB	ACDD			

ABBB
ABBD
ABDB
ABDD

ADBB
ADBD

ADDB
ADDD

Proof that 24 is maximum

1. From set of 26 we must eliminate both ACBB and ACDD.

If ACBB is included, then ADDD and ABDD are excluded; similarly, if ACDD is included, then ADBB and ABBB are excluded. Therefore both ACBB and ACDD must be eliminated, to achieve 25. ✓

~~[illegible]~~

Can a code of 25 be written down?

1. A••A cannot be excluded.

If all A••A are excluded then AAAB and AAAD are obligatory.✓ But both AD·· and AB·· must be included because of ~~both~~ the single choices ✓ A(no C, no A). This makes it impossible to have either ABAD or ADAB. Both are eliminated, hence 25 cannot be written. ✓

2. Compatibility systems.

III	ABAC	ACDC	ACAB
	ABAD		ADAB
	ACAD	ACBC	ADAC.

Choose $\boxed{\text{ABAD}}$. Excludes all ••AB. Eliminates ACAB.✓
choose ABAC or ACDC.

Choose $\boxed{\text{ABAC}}$. No restrictions.

Choose $\boxed{\text{ACAD}}$ excludes all ••AC not possible ✓
$\boxed{\text{ACBC}}$ excludes all ••AD not possible ✓
$\boxed{\text{ADAC}}$ possible.

Choice 1. $\boxed{\text{ABAD} \quad \text{ABAC} \quad \text{ADAC}}$

Choose $\boxed{\text{ACDC}}$ excludes all ••AB, also ADAC.

Choose $\boxed{\text{ACAD}}$ possible
$\boxed{\text{ACBC}}$ excludes all ••AD not possible. ✓

Choice 2. $\boxed{\text{ABAD.} \quad \text{ACDC} \quad \text{ACAD}}$

Choice 3. $\boxed{\text{ADAB} \quad \text{ADAC} \quad \text{ABAC}}$ B~D

Choice 4 $\boxed{\text{ADAB} \quad \text{ACBC} \quad \text{ACAB}}$

IV ~~[illegible]~~ ABCD ADCB
ABCB ADCD.

~~Must~~ If ABCD chosen then eliminate both ADCB ✓ and ADCB. ✓

Hence choices are 1. $\boxed{\text{ABCD ABCB}}$
2. $\boxed{\text{ADCB ADCB}}$

Note (a) not possible to exclude both ABC• and ADC• ✓
(b) both ~~•~~ ··CB and ··CD are obligatory endings. ✓

II AACB ACCD ACBA
AACD ACCB ACDA

Since both ••CB and ••CD are obligatory endings, it is not possible to have ~~both~~ ACBA and ACDA. Hence these can be eliminated. ✓

Choose AACB ~~excludes all beginning with ACB, since shown that •••A cannot be eliminated.~~ Also excludes all ACC(B/D) Hence the second choice must be AACD. This excludes all beginning with ~~ACD•, and this is impossible.~~

1. $\boxed{\text{AACB AACD}}$

Hence there is only ~~one~~ two choices here 2. $\boxed{\text{ACCD ACCB}}$ ✓ because ACCD excluded AAC(B/D)

I AABC ADCC ABCA
AADC ABCC ADCA.

choose AABC excludes all ABC• ~~[illegible]~~ ✓
leaves AADC and ADCA ~~[illegible]~~
AADC eliminates all ADC·, ✓ not possible.

AABC AADC

Hence (1) $\boxed{\text{AABC and ADCA}}$

Choose ADCC, eliminates all ABC(C/B/D) ~~AABC~~
AADC eliminates all ADC not possible

(ii) $\boxed{\text{ADCC and ADCA}}$ ✓

we now write down choices.

		excludes	
III 1	ABAD ABAC ADAC	all • • AB all AC • •	AABA AADA

Hence

II 1	AACB AACD	all ACC •	AAAC, ADAA, ACAA

I AABC, ADCA } ADCC, ADCA } ABCA, AADC } ABCA, ABCC }

IV ADCB ADCD ABCD ABCB

ABAA eliminates AAAD.

AACA

(no AAAD, AADA, ADAA)

ABBB eliminates AABB
ABBD

ABDB
ABDD eliminates AABD

ADBB
ADBD eliminates AADB

ADDB
ADDD eliminates AADD

ABBA
ABDA
ADBA
ADDA

of form A $\overset{no}{C}$ • •

ABBC or ADDC.

III 2. ABAD
ACDC
ACAD

eliminates
all ‥ AB

all ‥ BC, all ‥ AC

Hence from
II
must choose ACCD
ACCB

all ‥ BA all AAC·
all ‥ DA

I

ADCC, ADCA, ADCB, ADCD

ABCA, ABCC, ABCD, ABCB

ABCA, AADC, ABCD, ABCB

ABCA
AADC
ABCD
ABCB

ABAA
ACAA

ABAA
ACAA ACCC
AAAD ADAA

AABB
AABD
AADB
AADD
} eliminated

ADDC

+8

Consider ACAA and ACCC since ‥AA is obligatory, then ACCC is eliminated.

then ACAA is given. This eliminates all ‥CC

ADAA is eliminated
also AAAD

hence only ~~24~~ 20 with this choice.

$YZ, A, CCZ',$
$y3\ C\ A\ A$
$\longleftarrow$
$YZ, A, CY'C$
$y3\ C\ A\ y'A$

$W\ X\ Y\ Z \qquad \longrightarrow \qquad \bar{W}, X\ Y\ Z\ W, X\ Y$
$\bar{W}\ \bar{X}\ \bar{Y}\ \bar{Z} \qquad\qquad\quad \bar{W}, \bar{X}\ \bar{Y}\ \bar{Z}\ \bar{W}, \bar{X}\ \bar{Y}$

Then self with self in cycles

$YZ, A, X'CC,$
$y3\ C, x'AA$

$W_1 X_1 Y_1 Z_1, W_2 X_2 Y_2 Z_2 \longrightarrow X_1 Y_1 Z_1 W_1, X_2 Y_2 Z_2 W_2$

A, AAZ', A, XY
$A, AY'A, A, XY$
$A, X'AA, A, XYZ$

Rotation defective

Rules for $A, XYZ,$

AAZ' excludes $AZ'A + Z'AX$
$AY'A$ excludes $Y'AA + AXY$
$X'AA$ excludes $AAX + AXY$

Forwards

A in 1st position — see $A, \underrightarrow{AY'Z'}, A$ — fails

Then
$AY'Z'$ excludes $Y'Z'A$
$X'AZ'$ excludes $Z'AX$
$X'Y'A$ excludes AXY

A in 2nd place — i.e. $A, X'\underrightarrow{AZ', A}, X$

A in 3rd position — $A, X'Y'\underrightarrow{A, A, XY}$

Backwards

C in 1st position
$YZ\ A, CY'Z', A$
$\underleftarrow{y3\ CA}, A$

$CY'Z'$ excludes $C3y$

C in 2nd position
$Z, A, X'CZ', A$
$\underleftarrow{3\ C, x'A}$

$X'CZ'$ excludes $x'C_3$

$X'Y'C$ excludes $y'x'C$

C in third position
$A, X'Y'C, A$
$C\ x\ y\ A$

CCZ' excludes $C_{3y} + AC_3$
$CY'C$ excludes $y'AC + C_{3y}$
XCC excludes $Ax'C + x'C_3$

Summary of 4 letter codes.
beginning with A, plus some other restriction.

Sydney's first code $\quad A, \overset{no}{A}\ \overset{no}{A}\ \overset{no}{A}.$

This is

BBB CBC DBB
BBD CCB DBD
BCC CCC DCC
BDB CCD DDB
BDD CDC DDD

$\left.\begin{matrix} BBC \\ \text{or} \\ DDC \end{matrix}\right\}$ = 16

✓ o.k.

~~Sydn~~ Sydney's second code $\quad A, \cdot\ \overset{no A}{\cdot}\ \overset{no A}{\cdot}$

as above, plus $A \begin{matrix} B \\ D \end{matrix} \begin{matrix} B \\ D \end{matrix}$ = 20

My first code, corrected $\quad A, \overset{no}{C} \cdot \overset{no}{A},$ (nothing with two C's)

$A \begin{matrix} A \\ B \\ C \\ D \end{matrix} \begin{matrix} D \\ B \end{matrix}$ $\quad \begin{matrix} B & B & B \\ D & D & D \end{matrix}$ $\quad \begin{matrix} A \\ B \\ D \end{matrix} A C$ $\quad A \begin{matrix} B \\ D \end{matrix} C$ $\quad \begin{matrix} BBC \\ \text{or} \\ DDC \end{matrix}$ $\quad BC \begin{matrix} B \\ D \end{matrix}$ = ~~22~~ 24

My second code $\quad A, \cdot\ \cdot\ \begin{matrix} no\ A \\ no\ C \end{matrix}$

$\begin{matrix} A \\ B \\ D \end{matrix} \begin{matrix} B \\ D \end{matrix} \begin{matrix} B \\ D \end{matrix}$ $\quad \begin{matrix} A \\ C \end{matrix} A \begin{matrix} B \\ D \end{matrix}$ $\quad \begin{matrix} A \\ B \end{matrix} C \begin{matrix} B \\ D \end{matrix}$ $\quad \left[\text{or } DC\begin{matrix} B \\ D \end{matrix} \text{ instead of } BC\begin{matrix} B \\ D \end{matrix} \right]$ = 20

✓

The 26 Possible sets
of the form A, . . .

A ~ C B ~ D

· AAB ABA BAA

· BBB

· AAC ACA CAA CCC

· AAD ADA DAA

· DDD

ABC BCA DCC

ABD BDA

ACB CBA CCD

ADB DBA

ACD CDA CCB

ADC DCA BCC

· CBB CDD

· BBC DDC

· DBB

· BBD

· DDB

· BDD

BAC CAB CDC

BAD DAB

CAD DAC CBC

· BCB DCD

· BDB

· DBD

ABB BBA

ADD DDA

BCD DCB

also for the form

. . . A

Possible codes with A, · · ·

A
2

No C (where x)

~~no A~~

No A

	x x x	· x x	x · x	x x ·	x · ·	· x ·	· · x	· · ·
x x x	8	8	9	9	11	11	11	16
· x x	12	12	16	15	19	17	16	22
x · x	9	~~12~~	11	12	15	12	$\boxed{15}$	18 ?
x x ·	12	15	16	12	16	17	19	
x · ·					20		22	
· x ·								
· · x					24		20	
· · ·								?

, A, ; ·

A xyz, A,

Azyx

Rules for checking codes of the form A, . . .

A ~ C
B ~ D

Notation: A, XYZ, and any particular values in A, $X_0 Y_0 Z_0$,
C, xyz. C, $x_0 y_0 z_0$,
for all

Forward rules

~~A,XYZ~~ A, AY_0Z_0A, — AY_0Z_0 rejects Y_0Z_0A

A, X_0AZ_0, A, X — X_0AZ_0 rejects Z_0AX

A, X_0Y_0A, A, XY — X_0Y_0A rejects AXY

A, X_0AA, A, XYZ — X_0AA rejects AXY and AAX

A, AY_0A, A, XY — AY_0A reject Y_0AA and AXY

A, AAZ_0, A, XY — AAZ_0 rejects ~~AAZ_0~~ AZ_0A and Z_0AX

Backwards

YZ, A, CY_0Z_0, A, — CY_0Z_0 rejects C_{3y}
y3 CA

YZ, A, X_0CZ_0, A — X_0CZ_0 rejects x_0Cz
3 C x_0A

A, X_0Y_0C, A — X_0Y_0C rejects $y_0 x_0$ C
C $x_0 y_0$ A

Z, A, X_0CC, A — X_0CC rejects Ax_0C & x_0Cz
z C x_0AA C

YZ A, CY_0C, A — CY_0C rejects y_0AC & Czy
yz C A y_0 A C

XYZ, A, CCZ_0, A — CCZ_0 reject ACz & Czy
xyz C A A z_0

o.k. ✓

XYZ, A, CCC, A — CCC – AAC, AC3 & C3y
xy3, CAAA,

A ~ C B - D.

26 Sets of the form · A · ·

AAB ABA BAA

BBB

AAC ACA CAA CCC

AAD ADA DAA

DDD

—

ABC CAB ~~DCC~~ CDC

ABD DAB

ACB BAC DCC

ADB BAD

ACD DAC BCC

ADC CAD CBC

—

BCB DCD

CBB CDD

BDB

DBB

BDD

DBD

—

BCA CBA CCD

BDA DBA

CDA DCA CCB

BBC DDC

BBD

DDB

—

ABB BAB

ADD DAD

DBC BDC

ht

$h^+ \xrightarrow[2bc]{} h$

$h^+/2bc$ broth 10-5 h ht?

$h^+/2bc$ sm 10%.

T2L

T2L

T4c_1 c_1^+

T4c_3 c_3^+ 9

T6c_2 c_2^+

T2H

T2Hc^r

·4 S

45,000

30,000

30,000

2

2

PP/CRI/H/1/20/1

A~C B~D

26 Sets of the form · · A ·

AAB BAA ABA

BBB

AAC CAA ACA CCC

AAD DAA ADA

DDD

–

CAB BCA CCD

DAB BDA

BAC CBA CDC

BAD DBA

DAC CDA CBC

CAD DCA CCB

–

BBC DDC

BCB DCD

BBD

BDB

DBD

DDB

–

ABC ACB DCC

ABD ADB

ACD ADC BCC

CBB CDD

DBB

BDD

–

BAB BBA

DAD DDA

CDB CBD

–

A ↔ C
B ↔ D

Possible sets

AAAB } × DCCC }	AABC } (×) ADCC }.	BBAC } ✓ ACDD } ×	ABAC } × ✓ ACDC }
BBBA } CDDD }	AABD } BDCC }.	BBCA } ✓ CADD } ×	ABAD } BCDC }
AAAC } ACCC }	AACB } (×) DACC }.	BBAD }. BCDD } (×)	ACAD } ✓ BCAC } ×
AAAD } BCCC } ×	AADB } DBCC }.	BBDA }. CBDD } (×)	BABC } ADCD } ✓
BBBC } ADDD }.	AACD } BACC }.	BBCD } BADD }.	BABD }. BDCD }
BBBD } BDDD }	AADC } ABCC }.	BBDC } ABDD }.	BCBD } BDAD }.

AABB }
DDCC }.

ABCD }
BADC }

AADD }
BBCC }.

ABAB

(1)

If ABAC

then ABAA - ~~A,ABA~~

then ABAD - ~~ADAB~~

then AADA , ~~ADAA~~

then. ACAD ✓ ~~ADA,C~~

then neither AACA nor ACAA

(2)

If ACAB

then ADAB ~~ABAD~~

then ADAA ~~AADA~~

then and AABA ~~ABAA~~

and ACAA ~~AACA~~

and ABBC ~~ABBC~~ } incompatible.

then and ACAD

ACAD^B

ABAC

AACA

ADAC

etc.

nor ~~ACAA~~

Better

ACAB

then ✓ then

ACAA ABBC ✓

then

✓ ACAD ? incompatible.

D A
BC, AC
B
BACA

DC, AC
BACA

BC, AC
DACA

~~A~~BAC
CADA

DC, AC
BACA

AAAB AABA ABAA
2 1

~~AAAC~~ AACA ACAA ~~ACCC~~ ← both wrong with 1
2 2

AAAD AADA ADAA
1 2

... due to ..AA endings.

✓ ~~AABB~~ ABBA

✓ ~~AABD~~ ABDA

✓ AADB ADBA

✓ ~~AADD~~ ADDA

CACC

✓ ~~AABC~~ ABCA ~~ADCC~~

AADC ~~ADCA~~ ABCC

BACC CADC

ABCC

✓ AACB ~~ACBA~~ ~~ACCD~~

✓ AACD ~~ACDA~~ ~~ACCB~~

~~BA~~, AC
DC CA

AC, BA
CA, DC

DA

ABAD ADAB
1 2

ACBD

ACCC

ABAC ACAB ~~ACDC~~
1 2

~~CBAC~~
~~ADCA~~

AA, AC
CCCA

ADAC ACAD ~~ACBC~~
21

DC, AC
BACA

✓ ABCD ~~ADCB~~

✓ ABCB ~~ADCD~~

BC, AC
DA, CA

dilemme

ADAA
ABAA
...
AACB
...
ADAB

ABBC ADDC ← these make 2 impossible
1

BC, AC
DA, CA

BADC

~~ACBB~~ ~~ACDD~~

~~ABAA~~

and

A BBB
A DDD

AACB
ABAD or ADAB
AAAD or AADA or ADAA
~~AAAB~~ ~~AABA~~ ABAA

Suppose no A . AA

~~Then AABA~~

AA AB AABA

~~AAAC~~ AACA ACCC

AA AD AA DA

now with AB . . and ABAD

or AD . . or ADAB

∴ we must have an ending in . . AA

AB

AD

AA	BA
AB	AA
AC	CA
AD	DA
	AD
	AB
	AC

A1

consider AACA ACAA

then ~~ACAA~~ : ~~then we must have~~ ACAB

. . . . ADAB

. . . . AABA

ABBC

ADDC

AABA ABAA

ABAC ACAB

ABAC and ABAA and ABAD AADA

or ACAB and AABA and ADAB ADAA

incurve

A no.c . .

~~AAA~~BA
ABAA

AACA . . . .   CACC

AADA~~B~~

No . . AD

ABBA

AB DA

ADBA   . . AA

ADDA   . . ~~AB~~
. . AC
AD

ABCA   CADC

AADC . . .   ABCC   AA . .
AB . .
AD . .

AACB   DACC

AACD   BACC

~~ABAB~~ ABAD

ABAC   ACDC

~~ADAC~~ ACAD   ~~ACBC~~   ACAD

ABCD   BADC

ABCB   DADC   BC,AC

DACA

A ~~BB~~C - DD   ~~ADDC~~ ABDC

A B B B
A D D D

Choice narrowed to

$AC^{A}_{\substack{B\\C\\D}}$

AAAB AABA ABAA

AAAC AACA ACAA ACCC

AAAD AADA ADAA

.. CA

✓ ~~AABB~~ ABBA

✓ ~~AABD~~ ABDA

✓ ~~AADB~~ ADBA

✓ ~~AADD~~ ADDA

no A·AD

✓ ~~AABC~~ ABCA ~~ADCC~~

∴ ADC all forbidden

AADC ~~ADCA~~ ABCC

AACB ACBA ACCD

AACD ACDA ACCB

✓ ABAD (ADAB)

ABAC ACAB ACDC

ADAC ACAD ACBC

... for ABAD

... for AC..

A.C..

CD, AC
AB CA

ABCD ~~ADCB~~

ABCB ~~ADCD~~

ABBC ADDC

~~ACBB~~ ~~ACDD~~

and
$A^{BBB}_{DDD}\}$

ABCA
.CD,AC

AADC
CCBA

DADC
~~CDAB~~
~~AADC~~

AADC
CCBA

BACC

If we are to have 25 in the dictionary then we must have the following in it

(where · means something, not anything)

AB··   A·BB
AD··   A·DD
       A·BD
       A·DB

$\left.\begin{matrix} A\cdot BB \\ A\cdot DD \\ A\cdot BD \\ A\cdot DB \end{matrix}\right\}$ i.e. $A\cdot{}^{BB}_{DD}$

By inspection:

because of $\left.\begin{matrix} ABCD \text{ or } ADCB \\ \text{and } ABCB \text{ or } ADCD \end{matrix}\right\}$ we must also have

A·CB
A·CD

and $\left.\begin{matrix} ABC\cdot \\ \underline{\underline{OR}} \\ ADC\cdot \end{matrix}\right\}$ since we are entitled to one choice we

can say $ABC{}^{B}_{D}$ occurs   also A $ABC{}^{B}_{D}$ occurs

also Sydney has shown we must have as A··A

also because of ADBC & ADDC we must have A··C

Thus all letters must occur in the second position

If consider ABAD ADAB

and AAAB AABA ABAA

OTHER or AAAD AADA ADAA

Thus if ADAD but not ABAB then we must have it ADAB as members

See over. Must be an ending in ··AA

given ~~there must be AA..~~

There must be one ending in ..AA (given an ending in ...A)

For suppose there were <u>not</u>

then we must have AAAB AABA

and AAAD AADA

and we must have AB.. and AD..

~~If we have~~ consider ABAD or ADAB

if <u>ABAD</u>, then AABA and AAAB excluded

if <u>ADAB</u> then AADA and AAAD excluded

∴ must be an ending in ..AA

~~ABAD~~ ~~ad~~ or ~~ADAB~~

Terminal A eliminates

$AA\genfrac{}{}{0pt}{}{BD}{BD}$

∴ must have all ABBA

ABDA

ADBA

ADDA

~~or ABx~~

eliminate AABC ABCA or ~~ADCC~~

↓ NO

x, ADCC

x, CBA

must have ABCA

x, CDA

AADC or ABCC

ABAD

AADA

~~ABBC, AABA~~ ~~DDZA~~

ABAD ~ no ~ AABA ; ∴ AAAB or ABAA

Must Does AA.. occur ?

~~must Does A..A.. occur : yes~~

for 25 we must either have AA..

or AC..

~~if ,AC.. occurs~~ if ,AC occurs

~~, CA~~

$ABC\,{}^{A}_{\substack{B\\D}}$, AC

$A\,{}^{C}_{\substack{B\\D}}$, CA

$ABC\,{}^{B}_{D}$

consider $ACC\,{}^{C}_{\substack{B\\D}}$

or CAA

$ABCD^{B}$, AC

A^{B}_{D} , CA

∴ ACBA

or ACBA / impossible

II

∴ AACB } or ACCD }

AACD } or ACCB }

if AAC. then ACC not forbidden

AACB or AACD

or claim is ACC not

or

ACCD or ACCB

then AAC not

AVBC . eliminates

consider types ~~both~~ of the form ,A . A .,

Then AXAY eliminates all ~~ABC~~ $\underset{\cdot\cdot}{AX}$ and

I	F	I	F
, . .	. . ,	. .	. .

a list of all I and all F

eliminates F.I.

if $I_n = F_m$: if interior case . . / A .

and . . / . C

AB/AD or AD/AB

if ABAD then

ABCB or ADCD

AA$\overset{DC}{\cancel{BC}}$ or ADCA

AB,

AD, forbidden

|A . AB|
|A . AD|

if ABCB, then ,ABCB,A

,CDAD

A~C B~D

ACBB or ACDD or neither

if ACBB, then we have

ACBB,A ACBB,AC
ADDD CADD,CA

,ADDD,AC DD,ACBB
CBBB CA BBCA

Thus ACBB eliminates all A·DD

∴ eliminates $A^{B}_{D}DD$ ∴ 24

if ACDD, then BB,ACDD
DD,CA ∴ all A·BB
A·BB eliminated

∴ must eliminate both ACBB and ACDD

, × × · · ,

ABAD or ADAB ABAD

if ABAD

. . ,ABAD,A
,CDCB,C

we cannot have

in [illegible]

$\overset{F}{A} \cdot AB$ or $\overset{F}{A} \cdot AD$

∴ to have ABAD or ADAB

we must have either (1) ABAD and AB not [illegible] AB

(2) ADAB, and AD not [illegible].

Since B & D [illegible]

∴ Take ABAD ∴ AB cannot be [illegible].

∴ ABAC or ACDC }
and AABA or ABAA }

,ABAC,A
,CDCA,C

. . ,ACDC,A
. . ,CA

~~ACBB or ACDD~~

~~ACBB~~
CA

,ABBC,$A\overset{B}{D}\overset{B}{D}$
,CDDA,$C\overset{D}{B}\overset{B}{D}$

C^{B}_{D}, A^{B}_{C}
A^{B}_{D}, CA

,AABB,A

$\boxed{AA,}$

∴ ACBA
ACDA

[illegible]

AACB or ACCD }
AACD or ACCB }

A D
E
F

A D
B ~ E
C F
G
H

15

D
E ~ G
F H

6 = 21

15 same

A
B
C
D
G
H

x y z

1st 2nd 3rd

Start only Bolt Stop

C
A D
B ~ E 12
F
G
H

= 21

1 ~ 2 + 3 A ~ B 2 - 3

C F
D ~ G
E H

21

19

A E A ~ C 20
B ~ F B D
C G
D H

B
A
7
H

B E
C ~ F
D G
H

19

A D
B ~ E
C

D F
E ~ G
H

A D
B ~ E F
C G
H

6 9 21

AB A B

A B C A B C

A B D C

A B C D

$x + y + z = 8$

$N = x(y+z) + [illegible] + yz$

$= (xy + yz + zx)$ [illegible]

xz

xy

yz

$xx \quad yy$

$x=3$	$y=3$	$z=2$
A	D	G
B	E	H
C	F	

[illegible] 6

1	1	6		$1+6+1 = 8$
1	2	5		$2+10+5 = 17$
1	3	4		$3+12+4 = 19$
2	2	4		$4+8+8 = 20$
2	3	3		$6+9+6 = 21$

$x^2 + y^2 + z^2 + 2xy + 2yz + 2zx =$ constant n^2

$(x-y)^2 + (y-z)^2 + (z-x)^2$

$= 2(x^2+y^2+z^2) - 2(xy + yz + zx)$

$= 2n^2 - 6(xy + yz + zx)$

Possible Dance Code

1 2 3 | 4 5 6
1 4 7 | 1 4 7

1 2 3 | 4 5 6
7 1 4 | 7 1 4

1 2 3 | 4 5 6
4 7 1 | 4 7 1

123 or 456

147 or 258
or 369
or 36
all respectable

1 2 3 | 4 5 6
2 5 8 | 2 5 8

1 2 3 | 4 5 6
8 2 5 | 8 2 5

1 2 3 | 4 5 6
5 8 2 | 5 8 2

1 2 3 8 | 4 5 6 8
7 6 3 7 | 3 6 3 8

1 2 3 7 | 4 5 6 7
6 3 6 3 | 6 3 6 8

App per = Tyr

7 7 8 | 7 7 8
1 4 3 Try | [illegible] 5 6 Arn

8 8 7 | 8 8 7
1 4 7 Mar | 2 5 6 Mis

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

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

12

7 7 7 7 7 7
1 2 4 5 7 8

8 8 8 8 8 8
1 2 4 5 7 8

14
7
28
35

7

1 2 3 4 5 6
3 6 3 3 6 3

1 2 3 7 4 5 6
6 3 6 3 6 3 6

48

16

7 7 8 8 7 7 8 8 Arn
1 4 7 3 Tm 2 5 8 6

8 8 7 7 8 8 7 7 His.
1 4 7 3 2 5 8 6

1 2 3 4|5 6 7 8

Mer.

Thr ~~Val~~

~~Ser~~ ~~Ilea~~

Tyr ✓ Cys ✓

~~Pro~~ ~~Gpln~~

~~Asp~~ Gly ✓

~~Hys~~

Glu ✓

Ala

6 12

24 40

4

~~× A B~~

16

~~× A B~~

.Ala .. Glu

15 4

x X Y' x x

x x Z x x

O A B C D

O A B C D

1

2

2

2

2

2 11

2

2

14

4

56

53

15

45

~~14 × 4~~

13 × 4

$\boxed{12 \times 4}$

$\boxed{* \times}$

3.4 .. 8

1 1

4

2

① above 16

② c double.

A B X

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

7 8, 3 or 4

$3\,6\,{}^{7}_{8}$

$3n + (20-n)\begin{pmatrix}2\\8\\4\end{pmatrix}$

a.

·a

X Try

X Met

X Asn

X His

X = Asp
or Asn
or Tyr

$\begin{vmatrix} X & Z \\ Y & Y \end{vmatrix}$ $\begin{vmatrix} X & X \\ Y' & Z \end{vmatrix}$

X	W	X
Y	Y	Z

	Lys	Ser	Leu	Ala	Thre
Lys	1	1	1	4	2
Ser	1	✓	1	3	5
Leu	2	3	1	3	1
Ala	1	2	2	4	2
Thre	1	2	1	2	1

Gly
Cys
Arg
Val
Pro
Phe

Try
Met ?

Lys Ala
Lys Pro
Ser Gly
Ser Threo (5)
Gly Ser
Gly Cys
Gly Arg
Phe Val

320
32

Ala Lys
Ala Ala
Ala Gly
Val Leu
Val Ileu
Pro Threo

Gly : all but Gly Gly
Cys : all but Leu Cys
Arg : same.
Val : Val Val , Val Ile

1234 n 5 6 7 8

Group P   Gens Q

The all PQ forbidden

for all QP allowed

Consider the situation . . X A B P . .

and . . . Y A B Q . . .

Then

① Assume AB has the same sp in both,

Then X, Y must have overlapping ends

and P, Q must have overlapping beginnings.

His
Met
Try

64
8
512

123 or 456 or 78

147 or 258 or 367 or 368 or 143 or 256 or 36

or Glu N
or Glu

Then or His
Try
Asn

Try
Asn
His

~~Phe~~
~~Pro~~
Glu
~~Asp~~

Cycles of this form. A · ~A ·

Possible sets are. = 25

$, A, \begin{smallmatrix}A\\B\\C\\D\end{smallmatrix} \begin{smallmatrix}B\\C\\D\end{smallmatrix} \begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}, A,$

ABA

BBB

ACA, CCC

ADA,

DDD,

—

ABC BCA DCC

ABD ~~B~~ BDA

ACB CBA CCD

ADB DBA

ACD CDA CCB

ADC DCA BCC

—

CBB CDD

BBC DDC

DBB

BBD

DDB

BDD

—

CDC

CBC

BCB, DCD

BDB

DBD

ABB, BBA

ADD, DDA

BCD, DCB

~~Consider A, no A no C no A~~

Consider A, $\overset{\text{no C}}{\text{no A}}$: $\overset{\text{no C}}{\text{no A}}$

BBB

DDD

and. BAD, DAB

BcB, DcD

BcD, DCB

.: take. BC^{B}_{D} = 11

Can we ad ~~BAD~~ BAD ?

. A B, A, D .. ✓

Consider $A_{,\,no\,C}^{\,no\,A} \cdot no\,A$

and try BBB/DDD BCD^{B} BBC $^{B}_{D}AC$

= 13

and try to add one or more of

DCC

BCC

BAD ~ DAB

~~BCC~~ B A, DCC, A .. no $\underline{DCC}$

D C, BAA, C

2

$^{B}_{C}{}_{D}$, A, BCC, A Bcc ok. ✓

$^{A}_{B}{}_{D}$ C, DAA, C

. AB, A, D . .

A, BAD, A, $^{B}_{D}$ BAD ~ DAB ✓

~~A, DC~~

A, DAB, A, $^{B}_{D}$

~~AZDA~~ AD, A, B . .

$\boxed{\text{making 15 in all}}$

for A, no A · no A

~~we have the~~ consider CXX , A, CXX, A

. . , C, A

(then we also might have)

CCC

CCD

CCB

. . A, CC $^{C}_{D}{}_{B}$, A

. . C, A A $^{A}_{B}{}_{D}$ seen ok.

∴ probably 18

ie not DCC
nor CBB, CDD)

Consider A, no A no C no A.

we have B B B
D D D

and CBB } possibly.
CBB

CBB, CDD

BBC, DDC

BAC, CAB, CDC

BAD, DAB,

CAD, DAC, CBC

try BBC (we select)
BAC
DAC = 12
BAD

plus CBB ?

. . , A, CBB, A No
. . C, A

Consider A, no C no A no C no A

Then B B B
D D D

plus possibly BBC, DDC
BAC,
BAD, DAB,
DAC,

we can certainly have BBC
BAC
DAC

can we have BAD ? yes.

[illegible] c [illegible] 8 the 24 [illegible]

∴ = 8+4
= 12

A . , A, BAD, A, ^B_D
[illegible]

A B, A, D

X = BCD = Z   Y = all
x = ABD = 3   y = all

A_1 no $\tilde{A}$ · no $\tilde{A}$.

misleading

	CCC	DCC	CCD	CCB	BCC	CBB	CDD	BBC	DDC	BAC	CAB	CDC	BAD	DAB	CAD	DAC	CBC	BCB	DCD	BCD	DCB
CCC						×	×				×	×			×		×				
DCC																		×		×	
CCD						×	×				×	×			×		×				
CCB						×	×				×	×			×		×				
BCC																			×		×
CBB							×				×	×			×		×				
CDD						×					×	×			×		×				
BBC									×												
DDC								×													
BAC											×	×			×						
CAB						×	×			×	×?	×	×		×		×				
CDC						×	×			×	×	(3)			×		×				
BAD														×		×					
DAB										×			×								
CAD						×	×				×	×		×	×	×	×				
DAC											×				×	×?					
CBC						×	×				×	×			×	×	×				
BCB																			×		×
DCD																		×		×	
BCD																			×		×
DCB																		×		×	

Code of the form A, … A … A

we can choose from 20 possible sets

BBB ✓

of these 8 contain no A or C and are therefore ok.

CCC

DDD ✓

—

DCC

CCD

CCB

BCC

—

CBB or CDD

BBC or DDC

A,BAD,A, excludes DA$^{B}_{D}$

DBB ✓

BBD ✓

DDB ✓

BDD ✓

—

BAC, CAB, CDC

BAD, DAB

CAD, DAC, CBC

BCB DCD

BDB ✓

DBD ✓

—

BCD, DCB

,C,CCT,C,TCG

20
19

G 6

A, wA . wC

C in the middle.

	BCA	CCD	CCB	DCA	BCB	DCD	BCD	DCB
BCA						×		×
CCD								
CCB					×		×	
DCA						×		×
BCB					×		×	
DCD						×		×
BCD					×		×	
DCB								

✓
✓

omit.

∴ BCB
BCD
BCA
CCB
CCD

= 22

wC . A, BCA,
wA ∴ C, DA

wC ∴ A, CCD,
wA ∴ C AA ✓

. A, DCA
wA C, BA

. A, BCB,
wA C, DA

This leaves BAD, DAB

and possibility of CBA for CCD
CDA for CCB

$\overset{B}{\cdot}\ C\overset{B}{D}\ \ A, C\overset{D}{B}A,\ \times$

$. A\overset{D}{B}CA$

AB, A, D

Then code is $\begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix}$ $\begin{matrix}A\\B\\D\end{matrix}\begin{matrix}A\\B\\D\end{matrix}A$ $CA\begin{matrix}A\\B\\D\end{matrix}$ $BC\begin{matrix}A\\B\\D\end{matrix}$ $CC\begin{matrix}B\\D\end{matrix}$ = 22

A, no A . no C.

<u>Check</u>

$\begin{smallmatrix}D\\B\\C\end{smallmatrix}AA, A, \cdots$ ✓ $CA\begin{smallmatrix}B\\D\end{smallmatrix}, A, \cdots$ ✓

$C\begin{smallmatrix}B\\D\end{smallmatrix}A, A, \cdots$ ✓

in any case clear that the "sense" chain will be ok.

Check reverse chain:

$\overset{no\,C}{D}, A, \begin{smallmatrix}D\\B\end{smallmatrix} C A, A,$ $\cdots, A, C A \begin{smallmatrix}A\\B\\D\end{smallmatrix},$ ditto CBB

$\overset{no\,A}{B}, C\begin{smallmatrix}B\\D\end{smallmatrix}A$ ✗ $\cdots, C, A$ ✗

$D, A, \begin{smallmatrix}B\\D\end{smallmatrix} CB, A$ Thus many violations.

$B, C\begin{smallmatrix}B\\D\end{smallmatrix}A$ ✗

Thus which do <u>not</u> violate are. $\begin{smallmatrix}D\\B\end{smallmatrix}$ $\begin{smallmatrix}A\\B\\D\end{smallmatrix}A$ $\begin{smallmatrix}BBB\\DDD\end{smallmatrix}$ = 14.

and leave

✓ CAA

· BCA

· CBA, CCD

· CDA, CCB

· DCA

× ~~CBB~~, CDD – omit.

✓ CAB,

BAD, DAB,

✓ CAD

· BCB, DCD

· BCD, DCB

~~BB~~ A, C, BB

$BBCA$

. no C, A, C ..

. no A CA

∴ CA . ok.

CD

AB, C

A, ~A . ~C,

Is this the same as A, ~C . ~A, ?

If it were, it would be

D A B C D A B B B D D D C A A B D CB BD A BBC CBB B C B D.

~~check~~ BB DD A, A, B C o.k. ~~These are not the same.~~

Possible sets

BBB DDD = 25

and

~~AAB~~
~~BAAC,~~
~~AAD,~~
~~ABC, DCC,~~
~~ABD,~~
~~ACB,~~
~~ADB,~~
~~ARD,~~

BAA
CAA,
DAA,

BCA,
BDA
CBA, CCD
DBA,
CDA, CCB
DCA,

CBB, CDD

CAB
BAD, DAB
CAD,
BCB, DCD

BBA
DDA
BCD, DCB

~~A A~~ A

. . . A . . . A . . .

, A, A A D,

. , . A . . ,

, . . A . ,

, D A A , A,

, mA .

A, . mc mc , A,

CBB, CDD ✗

mA

A, mc mc . , A,

A BBC, DDC ?

A BBB
DDD

A, CBB, A

. . . C A DD, C

C A C

C

A mmc, C A

A C BB

ABB C A DDD

CA

AC

→

, A_2 [illegible] · C , A_2

[illegible] · A

←

A , C · [illegible] , A

←

→

, A C · · , A

· · C A

←

Possible sets for $A,\ \bullet\ \overset{\text{no}}{\underset{\bullet}{A}}\ \ \overset{\text{no}}{\dot{A}}$

BBB

CCC

DDD

ABC or DCC

✓ABD

ACB or CCD

✓ADB

ACD CCB

~~ABC BCC~~

\- ADC BCC

~~CBB~~ ~~CDD~~

BBC DDC

DBB

BBD

DDB

BDD

✓CDC

✓CBC

BCB or DCD

BDB

DBD

✓ABB

✓ADD

BCD or DCB

23 − 1 = 22

With C allowed in first position

we reject all C2y

Then reject $C\begin{smallmatrix}A & A\\ B & B\\ D & D\end{smallmatrix}$

Three code A . $\overset{\text{no}A}{.}$ $\overset{\text{no}A}{.}$

· BBB · CDC
· CCC · CBC
· DDD DCD
ABC (or DCC) · BDB
· ABD · DBD
· ADB CCD
· CCB · ABB
ADC · ADD
· BBC (or DCC) DCB
· DBB
· BBD
· DDB
· BDD

22

---

i.e. $\begin{matrix} B & B & B \\ D & D & D \end{matrix}$ (BL) $A \begin{matrix} B & \substack{C \\ B} \\ D & D \end{matrix}$ & $\substack{B \\ D}$L.

8 6

$CC\substack{B \\ C \\ D}$ 3

$C\substack{B \\ D}C$ 2

$DC\substack{B \\ D}$ 2

BBC 1

= 22

Test of code

Forwards

Backwards

$A \substack{B \\ D} \substack{C \\ B \\ D} \rightarrow \substack{B \\ D} \substack{C \\ B \\ D} A$ ✓

$DC\substack{B \\ D} \rightarrow BC\substack{A \\ B \\ D}$

$A\substack{B \\ D}C \rightarrow \substack{B \\ D}CC$ ✓

$BBC \rightarrow DDC$ ✓

$C\substack{B \\ D}C \rightarrow \substack{B \\ D}AC$ ✓ or $C\substack{A \\ B \\ D}\substack{A \\ B \\ D}$ ✓

$CCC \rightarrow AAC$ ✓, $AC\substack{A \\ B \\ D}$ ✓ $C\substack{A \\ B \\ D}\substack{A \\ B \\ D}$ ✓

$CC\substack{B \\ D} \rightarrow AC\substack{A \\ B \\ D}$ ✓ $C\substack{A \\ B \\ D}\substack{A \\ B \\ D}$ ✓

double checked ✓✓

First treat D as B.

A, . . . no A / no C

A

	AAB	ABB	ACB	CCB	CBB	BBC	CAB	BAB	BCB
AAB								×	
ABB									
ACB				×					
CCB			×		×				
CBB					×				
~~BBC~~						×			
CAB					×				
BAB								×	
BCB									×

This one ? rejects the one above.

$BA \begin{smallmatrix} A \\ B \\ C \\ D \end{smallmatrix}$

$Z = \begin{smallmatrix} B \\ D \end{smallmatrix} = Z_0$

$X = Y = x = y =$ call

<u>ACB</u>

$CC \begin{smallmatrix} B \\ D \end{smallmatrix}$

CBB

$C \begin{smallmatrix} B \\ D \end{smallmatrix} \begin{smallmatrix} A \\ B \\ C \\ D \end{smallmatrix}$

BCB

BCB

BBC

CAB

Thus only <u>ABB</u> is clean

CCB

ACB $CB \begin{smallmatrix} A \\ C \\ B \end{smallmatrix}$

A, · · no A / no C

Z = z = B/D

	AAB	AAD	ACB	CCD	ACD	CCB	CBB	CDD	BBC	DDC	CAB	BAD	DAB	CAD	BCB	DCD	BCD	DCB	
AAB												×							
AAD													×						
ACB				×		×													
CCD			×		×		×	×											
ACD				×		×													
CCB			×		×		×	×											
CBB							×	×											No
CDD							×	×											No
~~BBC~~									×	×									
~~DDC~~								×	×										
CAB							×	×				×							
BAD													×						No
DAB												×							No.
CAD							×	×					×						
BCB																×		×	
DCD															×		×		
BCD																×		×	
DCB															×		×		
							No	No				No	No						

Thus reject (CBB & CDD)

Code of the form A, · · no A
no C.

Possible selection.

✓ AAB

BBB

—

✓ AAD

DDD

—

—

✓ ABD

✓ ACB or ~~CCD~~

✓ ADB

✓ ACD or ~~CCB~~

—

~~CBB~~ or ~~CDD~~

~~BBC or DDC~~ —

DBB

BBD

DDB

BDD

✓ CAB

~~BAD~~ or ~~C~~ ~~DAB~~

✓ CAD

✓ BCB or ~~DCD~~

BDB

DBD

✓ ~~AAB~~ ABB

✓ ~~AA~~ ADD

✓ BCD or ~~DCB~~

23 poss

21 allowed

Code of the form $\qquad A, \overset{\text{no } C}{\cdot} \cdot \overset{\text{no } A}{\cancel{}}$

$A \begin{smallmatrix}A\\B\\C\\D\end{smallmatrix} \begin{smallmatrix}D\\B\end{smallmatrix} \qquad \begin{smallmatrix}B&B&B\\D&D&D\end{smallmatrix} \qquad \begin{smallmatrix}A\\B\\D\end{smallmatrix}AC \qquad \begin{smallmatrix}B\\D\end{smallmatrix}CC \qquad BBC \;(\text{or } DDC) \qquad \cancel{BAD} \;(\cancel{DAB})$

Thus
$$\left.\begin{array}{l} X = AB\;D \\ Y = ABCD \\ Z = \;BC\;D \end{array}\right\} \begin{array}{l} = z \\ = \cancel{z}\; y \\ = x\; x \end{array}$$

$A \begin{smallmatrix}B\\C\\D\end{smallmatrix} \begin{smallmatrix}D\\B\end{smallmatrix}$ rejects $\begin{smallmatrix}B\\C\\D\end{smallmatrix} \begin{smallmatrix}D\\B\end{smallmatrix} A$ ✓

$\begin{smallmatrix}B\\D\end{smallmatrix} AC$ rejects $CA\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓

BAD rejects $DA\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓

$AA\begin{smallmatrix}C\\B\\\cancel{D}\end{smallmatrix}$ rejects $A\begin{smallmatrix}C\\B\\\cancel{D}\end{smallmatrix}A$ ✓ and $\begin{smallmatrix}C\\B\\\cancel{D}\end{smallmatrix}A\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓

—

$AC\begin{smallmatrix}D\\B\end{smallmatrix}$ rejects $CC\begin{smallmatrix}A\\D\\D\end{smallmatrix}$ ✓

$\begin{smallmatrix}A\\B\\D\end{smallmatrix}AC$ rejects. $C\begin{smallmatrix}B\\D\\C\end{smallmatrix}C$ ✓

BBC reject. DDC ✓

$\begin{smallmatrix}B\\D\end{smallmatrix}CC$ $\qquad A\begin{smallmatrix}B\\D\end{smallmatrix}C$ ✓ , $\begin{smallmatrix}B\\D\end{smallmatrix}C\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓ $\quad \therefore$ ok.

ABCD ad   A $^{B}_{D}$ ~~BC~~

This code is

~~AAB~~
~~BBB~~
~~AAC~~
~~AAD~~
~~A~~DDD
~~ABC~~
~~ABD~~
~~ACB~~
~~ADB~~
~~ACD~~
~~ADC~~

~~BAC~~
~~DAC~~
~~BCB~~
~~BDB~~
~~DBD~~

~~ABB~~
~~ADD~~
~~BCD~~

12.

not BAD or DAB

~~BBC~~
~~DBB~~
~~BBD~~
~~DDB~~
~~BDD~~

A $\begin{matrix} A \\ B \\ C \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$

8

$\begin{matrix} B & B & B \\ D & D & D \end{matrix}$

8

A $^{B}_{D}$ C

BBC

$^{B}_{D}$ A C

AAC

~~BBC~~

B C $^{B}_{D}$

6   2   = 24

Better.

$\begin{matrix} B & D & B \\ D & D & D \end{matrix}$

A $\begin{matrix} B \\ C \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$ $^{B}_{D}$ A C   A A $^{B}_{D}$ ~~A $^{B}_{D}$ C~~   B C $^{B}_{D}$ $^{B}_{D}$ A C

~~$^{B}_{D}$ A C~~   A $^{B}_{D}$ C

AAC   AAC

A C $^{B}_{D}$ BBC

8
6
4
3
3

24

Abr CBB or CDD

either BAD or DAB — OR — AHB and AAD and CAB and CAD

Nor BAD or DAB

CBB or CDD

CBB rejects C $\begin{smallmatrix} B & B \\ D & D \end{smallmatrix}$

we can certainly have

BCB. + BCD (or DCD + DCB)

and BBC (or DDC)

and

If we must omit CBB and CDD

~~we can have.~~ because they exclude themselves.

we can then have ACB + ACD (or CCD + CCB)

Then we can have. AAB + AAD + CAB CAD or BAD or DAB

12 + 9 = 21

Possible sets for $A \overset{\sim A}{\cdot\cdot} \overset{\sim A}{\cdot\cdot} \overset{\sim A}{\cdot\cdot}$

m

	CCC	DCC	CCD	CCB	BCC	CBB (N_2)	CDD (N_2)	BBC	DDC	CDC	CBC	BCB (N_b)	DCB (N_b)
CCC						×	×						
DCC												×	
CCD						×	×						
CCB						×	×						
BCC													×
CBB						×	×						
CDD						×	×						
BBC									×				
DDC								×					
CDC						×	×						
CBC						×	×						
BCB													×
DCB												×	

$= 16$

$\therefore$ must reject CBB + CDD

then BBC or $\equiv$ DDC, the same

$X = Y = Z = B(C)D$

$xyz = B(A)D$

reject BCB + DCB

YZ A, CCC, A,

y YZC AAA, C

8

A, CBB, A

C ADD C

Possible sets for A $\underset{\bullet}{\tilde{A}}$ $\underline{\tilde{A}}$ $\underset{\bullet}{\tilde{A}}$

BBB

CCC

DDD

—

DCC

CCD

CCB

BCC

—

CBB or CDD

BBC or DDC

DBB

BBD

DDB

BDD

CDC

CBC

BCB or DCD

BDB

DBD

BCD or DCB

19

	AAB	AAC	ABC	BCC	ABB	ACB	BBC	BAC	BAB	BCB	
AAB									X		
AAC				[illegible]							–
ABC				X							+
BCC			X	X						X	
ABB											–
ACB											=
~~ACB~~ BBC							X				
BAC											✓
BAB									X		
BCB										X	

↑
This one

excludes the top one.

AAB
AAC
ABC
BCC
ABD
ACB
CCB
ADB
BBC
BAC
BAD

Check of my first code.

10. $A\,\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\,\begin{smallmatrix}D\\B\end{smallmatrix}$ $\quad \begin{smallmatrix}B\\D\end{smallmatrix}\begin{smallmatrix}B\\D\end{smallmatrix}\begin{smallmatrix}B\\D\end{smallmatrix}$ $\quad \begin{smallmatrix}A\\B\\D\end{smallmatrix}AC$ $\quad \begin{smallmatrix}B\\D\end{smallmatrix}CC$ $\quad BBC$ + BAD ? $= \underline{\underline{23}}$ 22

$A\,A\,\begin{smallmatrix}D\\B\\C\end{smallmatrix}$ excludes $A\begin{smallmatrix}D\\B\\C\end{smallmatrix}A$ ✓ or $\begin{smallmatrix}D\\B\\C\end{smallmatrix}AA$ ✓

$A\,\begin{smallmatrix}B\\C\\D\end{smallmatrix}\,\begin{smallmatrix}D\\B\end{smallmatrix}$ excludes $\begin{smallmatrix}B\\C\\D\end{smallmatrix}\,\begin{smallmatrix}D\\B\end{smallmatrix}\,A$ ✓

$\begin{smallmatrix}B\\D\end{smallmatrix}AC$ excludes $CA\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓

$AC\begin{smallmatrix}D\\B\end{smallmatrix}$ excludes $CC\begin{smallmatrix}D\\B\\A\end{smallmatrix}$ ✓

BBC " DDC ✓

$\begin{smallmatrix}B\\D\end{smallmatrix}CC$ " $A\begin{smallmatrix}B\\D\end{smallmatrix}C$ ✓ and $\begin{smallmatrix}B\\D\end{smallmatrix}C\begin{smallmatrix}B\\D\\A\end{smallmatrix}$ ✓

o.k.

Test BAD or DAB, CBB or CDD,

~~BAD excludes.~~ BAD ~~excludes DAB~~ excludes. $DA\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ etc. ∴ why not?

DAB .. $BA\begin{smallmatrix}A\\B\\D\end{smallmatrix}$

CBB excludes $C\,\begin{smallmatrix}B\\C\\D\end{smallmatrix}\,\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}$ few to add ∴ omit.

or CDD .. ..

CB X

or AB x

BCD

$DC^{B}_{C}{}_{D}$

DCB

$BC^{B}_{C}{}_{D}$

A, A A B, A, D

ADC BCB

DCC $DC^{B}_{C}{}_{D}$

ABC

AA^{C}_{B}

$BA^{A}_{B}{}_{D}$

$BC^{A}_{B}{}_{D}$

AAC AC~~A~~ or C~~AA~~ or ~~CCC~~

DA $^{B}_{D}$

$^{A}_{B}$ A $^{B}_{D}$

AAB AB~~A~~ BA~~A~~

ABA

$BA^{A}_{B}{}_{D}$

BAD or DAB

ADC

23.2 ~~Actual~~ repeats

12
3

ADC

X AB D

Y ABC D

Z BC D

BCC

BBD

DDD

BCC

ADC $DC^{A}_{B}{}_{D}$

A

ACB

ABC DCC

B

ABC BC^{B}_{C} CC^{B}_{C}

DCB

BAC

CBC

BC

Thus one tends to selects

ABC ✓

ADC ✓

BBC
or
DDC ✓

BAD
DAB ~ AAB and AAD

BCD
DCB .

BCB
DCB

AAB ~ ~~B~~ BAD

~~and~~ ~~AAD~~
=

AAD ~ DAB

~~if BCD~~ BCD and BCB

ABC ✓
ADC ✓
BBC ✓
AAB ✓
AAD ✓
BCD ✓
BCB ✓

17 + 7 = 24 !

Check of pur. TT pur
for Sydney code : i.e.

Let $T = A$. Then. $\overset{C}{\underset{B \sim D}{}} A A \overset{C}{\underset{B \sim D}{}}$

$\overset{A}{\underset{D \sim B}{}} C C \overset{A}{\underset{D \sim B}{}}$

both CCD and CCB occur.

(in my vision we could delete these:)

overlaps. $\overset{C}{\underset{B \sim D}{}}, A, A_{B \sim D}$ possible

Let $T = C$ Then reciprocal to above

Let $T = B$ $\overset{D}{\underset{A \sim C}{}} B B \overset{D}{\underset{A \sim C}{}}$

$\overset{B}{\underset{C \sim A}{}} D D \overset{B}{\underset{C \sim A}{}}$

. . . .

$\frac{1}{2}$

A . . .

$\frac{1}{20} \times \frac{1}{2} \times \frac{1}{4} = \frac{1}{160}$ a .6%

D B B D
A A

1st choice ~~...~~ ~~...~~ ~~DBB~~
A, BBD occur overlap DBB, A,
~~A, BBA~~ ABB, A

2nd choice A, DDB occur overlaps. BDD, A

Thus by eliminating from any 22 varieties we two, can always achieve a 20 code.

T = D: recip to above.

special check on

$A \begin{smallmatrix}B\\D\end{smallmatrix} C$ and $\begin{smallmatrix}\cancel{B}\\D\end{smallmatrix} C \begin{smallmatrix}B\\D\end{smallmatrix}$

$A, A \begin{smallmatrix}B\\D\end{smallmatrix} C, A,$

$C, C \begin{smallmatrix}B\\D\end{smallmatrix} A,$

$\cancel{\begin{smallmatrix}B\\D\end{smallmatrix} C A}$ ✓ ok.

$\begin{smallmatrix}B\\D\end{smallmatrix} C C$

$\begin{smallmatrix}B\\D\\C\end{smallmatrix}, A, \begin{smallmatrix}\cancel{B}\\D\end{smallmatrix} C \begin{smallmatrix}B\\D\end{smallmatrix}, A$

$\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ $C, \begin{smallmatrix}B\\\cancel{B}\end{smallmatrix} A \begin{smallmatrix}B\\D\end{smallmatrix}$

$\begin{smallmatrix}B\\D\end{smallmatrix} C \begin{smallmatrix}A\\B\\D\end{smallmatrix}$

$B C \begin{smallmatrix}\cancel{A}\\B\\D\end{smallmatrix}$ ✓

rejected DCC
ACB
ACD

12
=

$A, \; . \; \begin{smallmatrix}A\\C\end{smallmatrix} \; \begin{smallmatrix}A\\C\end{smallmatrix}$

$\begin{smallmatrix}B\\D\end{smallmatrix} \begin{smallmatrix}B\\D\end{smallmatrix} A, C B B, A$

$\begin{smallmatrix}B\\D\end{smallmatrix} \begin{smallmatrix}B\\D\end{smallmatrix} C A$

$\sim A$ $\sim A$

A, . . .

	CCC	ABC	DCC	~~ABD~~	ACB	CCD	~~ADB~~	ACD	CCB	ADC	BCC	BBC	DDC	CDC	CBC	BCB	DCD	~~ABB~~	~~ADD~~	BCD	DCB
CCC					x			x													
ABC			x																		
DCC		x														x				x	
~~ABD~~																					
ACB					·	x		·	x	·											
CCD					x			x													
~~ADB~~																					
ACD					·	x		·	x	·											
CCB					x			x													
ADC											x										
BCC										x							x				x
~~BBC~~													x								
~~DDC~~												x									
~~CDC~~																					
~~CBC~~																					
BCB																·	x			·	x
DCD																x				x	
~~ABB~~																					
~~ADD~~																					
BCD																	· x			·	x
DCB																	x			x	

X = x = all

Y = Z = B C D

y = z = (A) B D

x = (A) B C D

2 A, CCC, A

3, G, A A A

~~CDC~~ ABC

BCB
BCD
ADC
ACB
ACD

ABB
ACD
ABC

CCC
CCD
CCB

ADC
ABC

ACB
ACD
~~CCC~~

CCD
CCB

BCB
BCD
~~DCC~~

DCD
DCB
~~BCC~~

If
$\genfrac{}{}{0pt}{}{B}{D}$CC reject.

A$\genfrac{}{}{0pt}{}{B}{D}$C

and

$\genfrac{}{}{0pt}{}{B}{D}C\genfrac{}{}{0pt}{}{(A)}{\genfrac{}{}{0pt}{}{B}{D}}$

CCC

ABC
or
DCC

ADC ?

AAB

$A, AAB, A, \substack{\cancel{A} \\ B \\ C}$

$C, CCD, C \substack{C \\ B \\ B} A$

not $\cancel{\substack{D \\ B} CD}$

$A, AAB, A,$.

~~AAB~~ $BA \substack{A \\ B \\ D}$

Try $AA \substack{B \\ C \\ D}$

$A, AA \substack{B \\ C \\ D}, A, \substack{B \\ D} C$

$C, CC \substack{D \\ A \\ B}, C, \substack{D \\ B} A$

o.k.

$A, AC \substack{B \\ D},$

$A, AC \substack{B \\ D}, A, \substack{B \\ B} C$

$C, CA \substack{D \\ B}, C, \substack{D \\ B} A$

Thus for $A, \cdot \cdot \begin{matrix}\text{no } A\\ \text{no } C\end{matrix},$

code is

$\begin{matrix}C\\AA\\ \cancel{A}\end{matrix}\begin{matrix}B\\D\end{matrix} \quad \begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix} \quad A\begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix} \cdot \begin{matrix}A\\B\end{matrix}C\begin{matrix}B\\D\end{matrix} \quad \cancel{BBC} \quad \cancel{CAAB}$ $\cancel{BB}$ $= 27$

$\downarrow$

$\begin{matrix}A\\B\\D\end{matrix}\begin{matrix}B\\D\end{matrix}\begin{matrix}B\\D\end{matrix} \quad \begin{matrix}A\\C\end{matrix}A\begin{matrix}B\\D\end{matrix} \quad \begin{matrix}A\\B\end{matrix}C\begin{matrix}B\\D\end{matrix} \cdot$ <u>as before</u>

$A \frown C$
$B \frown D$

$\longrightarrow$

,ACCC, ABBB, ABCC, ADDB,
CAAA CDDD CDAA CBBD

$\longleftarrow$

check of my first code

A $\begin{matrix}A\\B\\C\\D\end{matrix}$ $\begin{matrix}D\\B\end{matrix}$ excludes. $\begin{matrix}A\\B\\C\\D\end{matrix}$ $\begin{matrix}D\\B\end{matrix}$ A

$\begin{matrix}A\\C\end{matrix}$ A $\begin{matrix}B\\D\end{matrix}$ excludes $\begin{matrix}B\\D\end{matrix}$ A $\begin{matrix}A\\C\end{matrix}$

C A $\begin{matrix}B\\D\end{matrix}$ excludes C $\begin{matrix}B\\D\end{matrix}$ C o.k.

$\begin{matrix}A\\B\end{matrix}$ C $\begin{matrix}B\\D\end{matrix}$ excludes $\begin{matrix}C\\D\end{matrix}$ C $\begin{matrix}B\\D\end{matrix}$

~~AAABD~~ with $\frac{B}{D}$ or end

AAAC}
ACCC}

AABC}
ADCC}

AADC}
ABCC}

BBAC}
ACDD}

BBCA}
CADD}

ABAC}
ACDC}

A BAD D - No

ACAD}
BCAC}

ACBB or ACDD

ACAB

~~ACAB~~ ACAD

~~BAD~~ no
or ~~DAB~~

A, AAC or

ruled out

ruled out

∴ ruled out
$\frac{B}{D}$ A C

D B A, $\frac{B}{D}$ C $\frac{B}{D}$, A,

B C, $\frac{B}{D}$ A $\frac{B}{D}$, A,

~~BABC~~
~~ADCD~~

~~ABAB~~

~~ABCD~~
~~BADC~~

Ruled out $\frac{B}{D}$ A $\frac{A}{B}{D}$

and $\frac{C}{D}$ C $\frac{B}{D}$

B C $\frac{B}{D}$

or D C $\frac{B}{D}$

$\frac{B}{D}$ A, $\frac{A}{B}$ C $\frac{B}{D}$, A

$\frac{B}{D}$ C $\frac{C}{D}$ A

Can one add CAB and CBB} ?
or CDD} o.k.

$\frac{B}{D}$ A

This ruled out $\frac{B}{D}$ A $\frac{A}{B}{C}{D}$ and $\frac{C}{D}$ C $\frac{B}{D}$

not CBB because

$\frac{B}{D}$ DD, A, C . . ,

BB C A

Thus we have (among some alternatives)

A B B A A B A C B C A D & ~~CBB~~ CDD
B D D D B D
D

12 2 4 2 = 20 19

B B B B A A B A B C A D ~~C~~ 19
D D D B D B D B CAD 20
D

48 6 4 2

check forward A 1st pass A, A . . A, pass fails . . A none.
2nd A, . A . A, pass fails . A . . .
A, . A $^{B}_{D}$ A, $^{A}_{B}_{C}_{D}$ pass - none.

backwards C . . B $^{BE}_{D}$ A, C . . . A, pass again CBD
D $^{A}_{B}$ C, A

why not CAD and CAB

A A
, B B B
D C D . = 24
D

Forward A in 1st. i.e. ,A, A . . ,A, i.e. false . . A none.

A in 2nd i.e. ,A, A A . ,A, . i.e. false . A .

i.e. B A A
D B
D

∴ omit BAB BAD DAB DAD i.e. B A B
D D

A in 3rd: none.

Backwards .

C in middle . ,A, . C . ,A,

. C, . A . ,C, A

∴ B . A, A C
D B
D

B C C A
D B
D

Then A B B A A B A C B B C B not BAB
B D D D D = also B C B
D D or B C B D D.
D

12 2 2 = 18

Forward A in 1st. ,A, A . . , A, i.e. false . . . . A none

A in 2nd. ,A, A A . . A, i.e. false . A .

i.e. A A B
D

from ,A, . A A, A, B none.
D

A in 3rd none

Backwards C in m 2nd B , A, A C B, A,
D D

B C, C A . , A,
D D

A ~ C   B ~ D.

ABD ADB ABB : ADD
CDB CBD CDD or BB

. . . A . . . A . . . A . . . A . . .
+ C . . . C . . . C . . . C . . .

B.C.D.

3×3×3 = 27

ABDCABDCA
CDBACDBAC

ACBDACBDA
CADBCADBC

ACDBACDBA
CABDCABDC

ADBCADBCA
CBDACBDAC

BBB
BBC
BBD
BCB
BCC
BCD
BDB
BDC
BDD

CBB
CBC
CBD
CCB
CCC
CCD
CDB
CDC
CDD

DBB
DBC
DBD
DCB
DCC
DCD
DDB
DDC
DDD

27
-4
-4
19

$\boxed{19}$ +1 or 2

BDCABBCA
ACDDAC

CADDCA
ACBBAC

CBABCBA
ADCDADC

CCABCCA
AACDAAC

ACCCA
CAAA

BBC
DDC

BCB
DCD

BCD
DCB

BCDABCDA
ABCDABC

BDCABDCA
ACDBAC

ACDBACDBA
CABDCABDC

BDC
BDAC

DBC
DBC

~~ADC~~

DBCADBCA
ACBDAC

CCBACCBA
AADCAADC

CBBACBBA
ADDCADDC

CBB
CDD

BBABBBA
DDCDDDC

DCCADCCA
BAACBAAC

ACBDACBDA
CADBCADBC

ACBCACBCA
CADACADAC

CBD
CBD

CDB
CDB

Thus code would be

BBB	~~CBB~~ CBC	DBB		ABD
BBD	CCB	DBD	BBC } or DDC	ADB
BCC	CCC	DCC		ABB
BDB	CCD	DDB		ADD
BDD	CDC	DDD		

A B D   B D   B D   12

C C B C D   3

C B D C   2

B D C C   2

\+ BBC or DDC } 1

= 20

That is   A B D   B D   B D   B D C C   C B D C   C C B D   CCC

and BBC or DDC }

ie. A B D   B D   B D   C → B D → C   + CCC + BBC or DDC }

29
20
24
73
11
62

248

Ass. Seq. [illegible]

what does $\overset{C}{\underset{D}{B}}BB$ reject?

either $A, \overset{A}{\underset{D}{B}}BB, A, C \ldots$

or $C\cancel{A}, \begin{smallmatrix}A\\D\\B\end{smallmatrix}DD, C, A \ldots$

or $A, \overset{C}{\underset{D}{B}}BB, A, \begin{smallmatrix}B\\C\\D\end{smallmatrix}\ C$

$C, \begin{smallmatrix}A\\D\\B\end{smallmatrix}DD, \overset{C}{\cancel{A}}, \begin{smallmatrix}D\\A\\B\end{smallmatrix}\ A$

ie reject CDD

$\overset{\cancel{D}}{\underset{\cancel{B}}{A}}CD$

$\therefore$ if we reject $\overset{C}{\underset{D}{B}}BB$ we can have CDD or ACD

Similarly if we reject $\overset{C}{\underset{D}{B}}DD$ … CBB or ACB

suppose we had ACD.

$\begin{smallmatrix}B\\D\\C\end{smallmatrix}\ A, ACD, A,$

$\begin{smallmatrix}D\\B\\A\end{smallmatrix}\ C, CAB, A,$

no CDA – [illegible]

no ~~[illegible]~~ D

no CCB

ie reject [illegible]

ACBC

try CCC

, A, . AA, A, C . .
C, . CCC, A . . no

or A, . . A, A, A C
C, . . C, C, C A no.

or A, . . . , A, A A C
C, . . . , C, C C A no.

∴ no overlaps, a reciprocal chain.

overlaps or forward chain must contain A.

∴ test. A $\begin{matrix} B & B \\ D & D \end{matrix}$

A $\begin{matrix} B & B \\ D & D \end{matrix}$ ie. A, . . A, A, $\begin{matrix} B & B \\ D & D \end{matrix}$ ∴ no

This code o.k.

what does $\begin{matrix} C \\ B \\ D \end{matrix}$ B B reject?

A, $\begin{matrix} C \\ B \\ A \end{matrix}$ B B, A, ~~BB~~
C, $\begin{matrix} A \\ D \\ B \end{matrix}$ D D, C

ie. allowing CDD and CCD rejects $\begin{matrix} C \\ B \\ D \end{matrix}$ B B ∴ 60 one less.

ie. CDD - one or c.
and $\begin{matrix} C \\ B \\ D \end{matrix}$ C D

in effect B C C D
and C D D

Simly. allowing CBB and CCB rejects $\begin{matrix} C \\ B \\ D \end{matrix}$ D D

A, $\begin{matrix} B \\ C \\ D \end{matrix}$ D D, A . . .
B B, C, . . .

reject CBB
or $\begin{matrix} C \\ D \\ B \end{matrix}$ C B

A only in common position

A . . . A . . . A . . . A . . . A
C . . . C . . . C . . . C . . . C

Three situations (1)

A . . . A . . C A
. C . . A

$\therefore$ A $\begin{smallmatrix}B\\D\end{smallmatrix}$ $\begin{smallmatrix}B\\D\end{smallmatrix}$ C

C $\begin{smallmatrix}D\\B\end{smallmatrix}$ $\begin{smallmatrix}D\\B\end{smallmatrix}$ A

ie. BBC, DDC } alternative.

~~BDC~~, ~~DBC~~ self reciprocal.

(2)

A . . . A . C . A
C . . . C . A . C

$\times$. $\times$ $\begin{smallmatrix}B\\D\end{smallmatrix}$ A $\begin{smallmatrix}B\\D\end{smallmatrix}$ C $\begin{smallmatrix}B\\D\end{smallmatrix}$ A

$\times$ $\times$ $\begin{smallmatrix}D\\B\end{smallmatrix}$ C $\begin{smallmatrix}D\\B\end{smallmatrix}$ A $\begin{smallmatrix}D\\B\end{smallmatrix}$ A

BCD }.
DCB }.

BCB }.
DCD }.

~~[illegible]~~

.DCD
.DCB
.BCD
.BCB

all these must — not be rejected by $\alpha\beta$ condition.

(3)

A . . . A C . . A
C . . . C A . . A

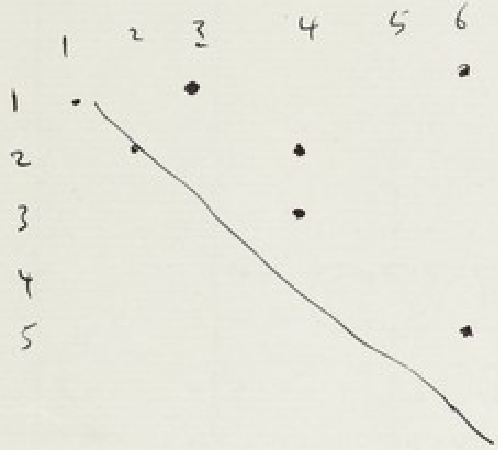
ie. A . $\begin{smallmatrix}B\\D\end{smallmatrix}$ $\begin{smallmatrix}B\\D\end{smallmatrix}$ A C . . A

. $\begin{smallmatrix}D\\B\end{smallmatrix}$ $\begin{smallmatrix}D\\B\end{smallmatrix}$ C A

ie. CDD, CBB }

~~CDB~~, ~~CBD~~ self reciprocal.

$\therefore$ choice ~~ie~~ either ~~reject~~ allow CDD and ~~allow~~ reject BBR, CBB + DBB
. . . . BDD CDD + DDD
or allow CBB
or allow ~~BBR~~ neither. ie. and reject CDD + CBB


1 2 3 4 5 6
1 2 3 4 5

Pker

overlaps a reciprocal

check this ~~ABB~~ to mold on

A, . . . A,
C . . . C,

all = A B B
B D D
D

to fix due to overlap is impossible, because they contain no C.

try BCC.

A, . . A,A, D C . no
C, . . C,C, B A .

or A, . . . A, A D C no
C . . . ,C, C B A

try BCC as over, B D, no.

try CBC

A, . A D, A, C . . no
C, . C B, C, A . . .

or A, . . ., A, D A C no.
C, . . ., C, B C A

try CDC as above B D no.

try CC B

A, . D A, A, C . . no
C, . B C, C, A . .

or A, . . D, A, A C . no
C, B, C, C A .

try CCD as above B D

try ~~CCC~~ BBC

A, . . ., A, D D C . no if no DDC
C, ,C, B B A , and vice versa.

Thus suppose we reject. BCD / DCB } and BCB / DCD } and CDD / CBB }

But perhaps allow either BBC or DDC

This gives us <u>16</u>.

$\longrightarrow$
.. ABBCA ..
CDDA

To this we can add some of these

— A, AAB, A / CCDC or A, ABA, A / CDCC or A, BAA, A / C, DCCC

— A, AAD, A / CCBC or A, ADA, A / CBCC or A, DAA, A / BCCC

— A, ABD, A / CDB, C or A, BDA, A / DBC, C
✓

✓ — A, ADB, A / CBDC or A, DBA, A / BDCC

— A, BAD, A / DCBC or A, DAB, A / BCDC

✓ — A, ABB, A / CCDDC or A, BBA, A / CDDCC.

✓ — A, ADD, A / CBBC or A, DDA, A / BBCC

Pu. T. T. Pu

lev T = C

ct A, B be Pun

$\begin{smallmatrix}A\\B\end{smallmatrix}$ C C $\begin{smallmatrix}A\\B\end{smallmatrix}$

ACCB

BCCA

$\begin{smallmatrix}C\\D\end{smallmatrix}$ A A $\begin{smallmatrix}C\\D\end{smallmatrix}$

.. C, A, A D B ...

rare

lev T = B

D, A = purines.

$\begin{smallmatrix}A\\D\end{smallmatrix}$ B B $\begin{smallmatrix}A\\D\end{smallmatrix}$

ABBD

DBBA

$\begin{smallmatrix}C\\B\end{smallmatrix}$ D D $\begin{smallmatrix}C\\B\end{smallmatrix}$

—

lev T = B

D, C be pun

$\begin{smallmatrix}C\\D\end{smallmatrix}$ B B $\begin{smallmatrix}C\\D\end{smallmatrix}$

—

$\begin{smallmatrix}A\\B\end{smallmatrix}$ D D $\begin{smallmatrix}A\\B\end{smallmatrix}$

ADDB

BDDA

lev T = B

D, A be pun

$\begin{smallmatrix}A\\D\end{smallmatrix}$ B B $\begin{smallmatrix}A\\D\end{smallmatrix}$

ABBD

DBBA

$\begin{smallmatrix}C\\B\end{smallmatrix}$ D D $\begin{smallmatrix}C\\B\end{smallmatrix}$

lev T = A

C + B be pun

$\begin{smallmatrix}C\\B\end{smallmatrix}$ A A $\begin{smallmatrix}C\\B\end{smallmatrix}$

$\begin{smallmatrix}A\\D\end{smallmatrix}$ C C $\begin{smallmatrix}A\\D\end{smallmatrix}$

DCCA

ACCD

Pu T T Pu

Pyr A A Pyr

Then all adjacent

have two cc. !!

,A, D ~~A~~ B, A, C   A B ~~D~~ A B B D
C B ~~C~~ D C A   C D ~~B~~ B C

C B B
B C B
D B C
C D D
D C D
D D C
~~C B D~~
B C D
~~B D C~~
~~C D B~~
D C B
~~D B C~~

,A, A B B, A, C ✓
C C D D C A A allow

,A, A D D, A, —

A, A B D, A, —

A A D B, A, —

$4 + \frac{y}{2} = 8$

$27 - 8 = 19$

A B B
A B D
A D B

,A, A D D, A, C
C, C B B C A

,A, A B D A, C ✓
C C D B C A

[not ADD]

,A, A D B A C ✓
C, C B D C A

,A, A D D, A, C
C C B B C A

A 1
T 1
G 2
C 2

A C C C A C C C A
C A A A C A A A C

$\overrightarrow{CDB}$

$\underleftarrow{ABD}$ allowed reject

BCD

$\underleftarrow{DAB}$

A, $\underrightarrow{CDB}$, A, CDB, A

CA$\underleftarrow{BD}$C ABD A

$\underleftarrow{ADB}$

A, ABB, A, BC
C C D D C A A ✓

ABB

, A, A ~~BD~~, A, ~~B~~ C
~~C C D B C~~ D A
no

~~A~~

A, ADB, A, B C ✓
C C B D C D A

ADB

~~A BB A~~
~~C D D C C A~~

A A A A, . . A, A A A A A

, A, A, A, C
C C C A

ABB

, A, A B B, A,
C C D D C

, A B B	, A D B	, C	, B C	D C	. . C
C D D	C B D	A	D A	B A	A
no	no	no	no	no	no

ADB

, A, A D B, A,
C C B D C

, A B B,	A D B,	, C	, B C	, D C
C D D	C B D	A	, D A	, B A
no	no	no	no	no

So one can have both if precision pairs selected correctly.

~~Pu T T Pu~~

A ~~C C~~ A
B ~~C C~~ B

RNA att - Ad-

+ Amino acid phosphate

RNA + Ad phosphate amino acid

, ABA, ABA, CCD, AAA, ADC,

AB A B

A B C A B C

A B C D A B C D

2

6

12

= 20

ABA
ABB
ACA
ACB
ACC
BC

~~BB~~

BDD, BCC, ABB, CDA,

--- BDDBCCABBCDA ......

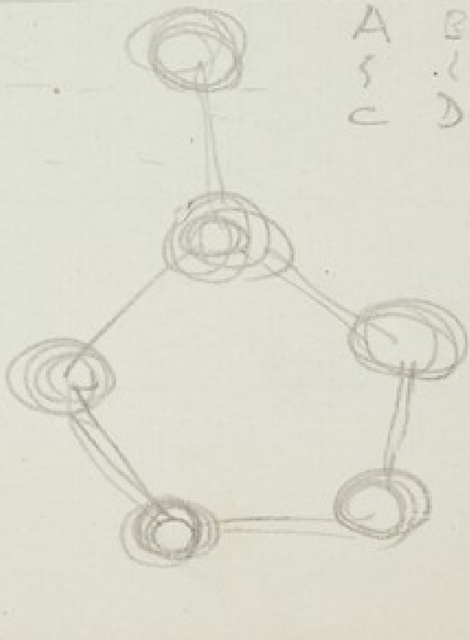
sense →

, BDD, BCC, ABB,

DBB, DAA, CDD,

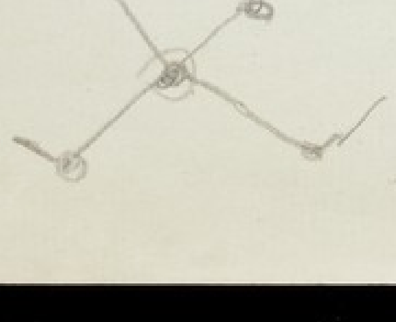
← nonsense

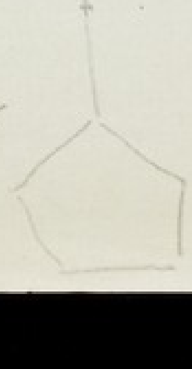
A B
C D



↑↓

, ABDD, - - - ,





A	C
B	D
C	A
D	B
A	C
C	A
D	B
C	A
D	B
A	C

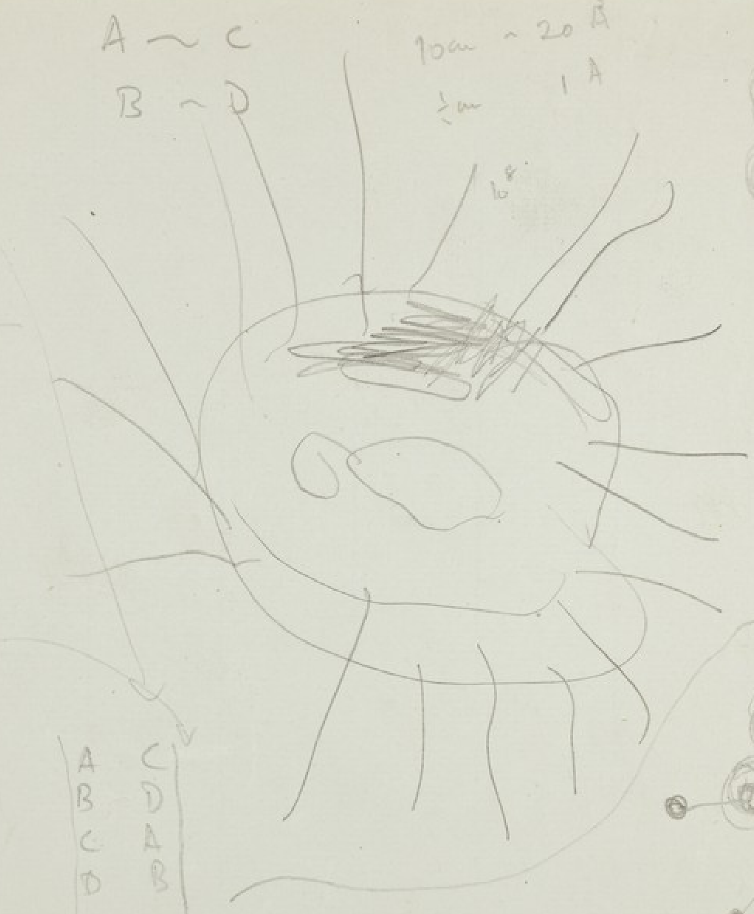
A ~ C

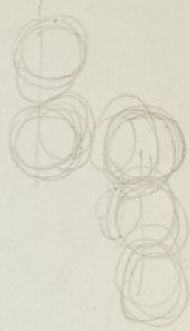
B ~ D

10cm ~ 20 Å

$\frac{1}{2}$ cm 1 Å

10^8



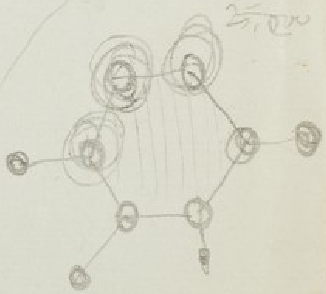


2 meters

10^8 meters

100,000 km

~~25,000~~



A	C
B	D
C	A
D	B
A	C

A	C
B	D
C	A
D	B
A	C

$\begin{matrix} A \\ B \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} A \\ C \end{matrix}$ A $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} A \\ B \end{matrix}$ C $\begin{matrix} B \\ D \end{matrix}$ → (or $D\,C\begin{matrix} B \\ D \end{matrix}$)

12   4   4   2   2 $= 20$

$A, \cdot \cdot \begin{matrix} \text{no } A \\ \text{no } C \end{matrix}$

Check. forward

A in 1st $A, A \cdot \cdot, A, \cdot$ from both $\cdot \cdot A$ none

A in 2nd $A, \cdot A \cdot, A, \cdot$ from both $\cdot A \cdot$

$A \begin{matrix} B \\ D \end{matrix}, A, \begin{matrix} A \\ B \\ C \\ D \end{matrix}$ from   none

backwards

C in 1st $\begin{matrix} B \\ D \end{matrix} \xleftarrow{\text{No}} A, C \cdot \cdot, A, \cdot$ none.

$\begin{matrix} B \\ D \end{matrix} A\, C, A$ ←

C in 2nd $\begin{matrix} B \\ D \end{matrix} A, \begin{matrix} C \\ D \end{matrix} C \cdot, A,$ (No)

$\begin{matrix} B \\ D \end{matrix}\, C\, \begin{matrix} A \\ B \end{matrix}\, A$ ←

C in 3rd   none.

one

$B\,A$

$C\, C \begin{matrix} B \\ D \end{matrix}$

Thus $\begin{matrix} A \\ C \end{matrix}$ A $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} A \\ B \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} B \\ D \end{matrix}$ $\begin{matrix} A \\ B \end{matrix}$ C $\begin{matrix} B \\ D \end{matrix}$ (or D) $= 20$

$= A, \cdot \cdot \begin{matrix} \text{No } A \\ \text{no } C \end{matrix}$

Thus 22 code is

A $\begin{matrix} A \\ B \\ \underline{C} \\ D \end{matrix}$ $\begin{matrix} D \\ B \end{matrix}$ B B B / D D D $\begin{matrix} A \\ B \\ D \end{matrix}$ A. $\underline{C}$ $\begin{matrix} B \\ D \end{matrix}$ C $\underline{C}$ BB$\underline{C}$ or DD$\underline{C}$

8 8 3 2 1 = 22

(no C . no A)

<u>Forward</u> only need consider those that contain A. A, A · · A,

A in first posn. fine. A, · · A nothing.

A in second place A, · A ·, A

ie A A $\begin{matrix} B \\ C \\ D \end{matrix}$?? nothing

~~A, A, AA~~

no A in third place $\begin{matrix} B \\ D \end{matrix}$ A $\begin{matrix} C \\ \text{no} \end{matrix}$ A, C A · nothing

<u>Backwards</u> only need consider the C's

C in first posn. – none

C in second place · A, · C · , A,

· C, · A · , C

C in third posn

A, · · C, A only case ·, A, $\begin{matrix} B \\ D \end{matrix}$ C

C, · · A, · no C C $\begin{matrix} B \\ D \end{matrix}$ A

Cases A, $\begin{matrix} A \\ B \\ D \end{matrix}$ A C, A | A, $\begin{matrix} B \\ D \end{matrix}$ C C, A | A, BBC A · A, A C

C · $\begin{matrix} C \\ B \\ D \end{matrix}$ C A, C | C, $\begin{matrix} B \\ D \end{matrix}$ A A, C | (C) D A C . C C A

Try codes of this form. (Generalized triplets)

A . . C (not C)

what does A, CBC, A reject?

A. D A, CBC, A, — ie. rejects DAC, CAD, all CA,

C B C, ADA, C,

in general A, -

Try rejecting all with C.

15 is upper limit. ✓

G C — G C

A ~ T

what does A, $\begin{matrix}A\\B\\D\end{matrix}$ $\begin{matrix}B\\D\end{matrix}$ $\begin{matrix}B\\D\end{matrix}$, A, reject?

ie C, $\begin{matrix}C\\D\\B\end{matrix}$ $\begin{matrix}D\\B\end{matrix}$ $\begin{matrix}D\\B\end{matrix}$, C, $\begin{matrix}C\\D\\B\end{matrix}$

it rejects A2 triplets $\begin{matrix}B\\D\end{matrix}$ $\begin{matrix}B\\D\end{matrix}$ A,

~~and AC DB B ie CBB~~

and

Test Code

$\begin{matrix}A\\B\\D\end{matrix}\ \begin{matrix}B\\D\end{matrix}\ \begin{matrix}B\\D\end{matrix}\qquad \begin{matrix}B\\ \end{matrix}\begin{matrix}B\\D\end{matrix}\,C\,C\qquad A\,A\begin{matrix}B\\C\\D\end{matrix},\ \cancel{AA}\qquad A\,C^{B}_{D}\qquad BBC$ or DDC

$A,\ \underset{\text{no } C}{\cdot}\ \cdot\ \underset{\text{no } A}{\cdot}\qquad {}^{B}_{D}AC\qquad = 20$

£105
23
82

2

£4.12.0
2.2.0
£2.10.

To get . . , $A,\ \begin{matrix}A\\B\\D\end{matrix}\ \begin{matrix}B\\D\end{matrix}\ \begin{matrix}B\\D\end{matrix},\ A,\ \begin{matrix}B\\D\end{matrix}\ C$

$C,\ \begin{matrix}C\\D\\B\end{matrix}\ \begin{matrix}D\\B\end{matrix}\ \begin{matrix}D\\B\end{matrix},\ C,\ \text{no}\begin{matrix}B\\D\end{matrix}\ A\ \ A$

o.k

7.0
11.6
23

$A,\ \begin{matrix}B\\D\end{matrix}CC,\ A,\ .$

$C,\ \begin{matrix}D\\B\end{matrix}AA,\ C,$

o.k

$A,\ \begin{matrix}B\\D\end{matrix}CC,\ A,\ \begin{matrix}B\\D\end{matrix}\ C,$

$\cancel{C,\ \begin{matrix}D\\B\end{matrix}AA,\ C,\ \begin{matrix}B\\D\end{matrix}\ A,}$

$A,\ AA\begin{matrix}B\\C\\D\end{matrix},\ A,\ \begin{matrix}B\\D\end{matrix}\ C$

forbidden is

$\begin{matrix}B\\C\\D\end{matrix}\ A\ \begin{matrix}A\\B\\D\end{matrix}$

$A\begin{matrix}B\\C\\D\end{matrix},\ A,\ \begin{matrix}A\\B\\D\end{matrix}$

$C,\ CC\begin{matrix}D\\A\\B\end{matrix},\ C,\ \begin{matrix}B\\D\end{matrix}\ A$

$A,\ AC^{B}_{D},\ A,\ \begin{matrix}B\\D\end{matrix}\ C$

$C,\ CA^{B}_{D},\ C,\ \begin{matrix}D\\B\end{matrix}\ A$

$A,\ BBC,\ A,\ \begin{matrix}B\\D\end{matrix}\ C$

$C,\ DDA,\ C,\ \begin{matrix}D\\B\end{matrix}\ A$

How many altogether are there of this form

A, $\overset{noc}{\cdot}$. no A.

A, AAB

A, BBB

A, AAC

A, AAD

A, DDD

—

A, ABC or A, DCC

A, ABD

A, ACB

A, ADB

A, ACD

A, ADC or A, BCC

—

A, BBC or A, DDC

A, DBB

A, BBD

A, DDB

A, BDD

A, BAC ~~or A, CDC~~

A, BAD or A, DAD

A, DAC

A, BCB or A, DCD

A, BDB

A, DBD

A, ABB ~~or AB~~

A, ADD

A, BCD or A, DCB

= 25 − 3 = 22

$^{B}_{D}CC$

A D B $A\,^{A\ B}_{C\ D}$ ~~A~~ AAC   BBC
B B B
D   or
DDC

12   4

(BC) (BC)
A D D $A\,^{A\ B}_{C\ D}$ BD (DC) C
B B B   (AA)
D   (BB)

12   4   4

A
A B D   B B B   ~~BC~~ $^{B}_{D}CC$ AAC   BBC
C B   D D D   B   or
D   D   DDC

8   8

---

can we add A,BAC — yes
A,BAD or A,DAB ? — no
A,DAC

A,BAB, ABAB
CDCD CDCD

A, BAC, A, $^{B}_{D}$ C
C, DCA, C, $^{B}_{D}$ A ✓

A, BAD, A, . .
~~C,DCA~~
AB, A, D
✓ ✓

A, DAC, A, $^{B}_{D}$ C
C, BCA, C, $^{B}_{D}$ A

Try ,A,$^{no}_{C}$ . .

This leaves A B D, B B D D, B D D, B_D C C, BBC or DDC and not $C\,^B_D\,C$, $C\,C\,^B_D$, CCC

15 5

What can we ~~say~~ add to this?

First, one at a time.

A, AAB or A, ABA or A, BAA

A, AAC or A, ACA no

A, AAD or A, ADA or A, DAA

A, ACB or ~~A, CBA~~

A, ACD

~~A, AAC~~

A, BAC

A, BAD or A, DAB

A, DAC

A, BCB or A, DCD

A, BCD or A, DCB

26

DA $^{B}_{\substack{C\\D}}$

BC 2

C . .

A, BBC

CDD, A

BC $^{\cancel{B}}_{D}$

reject

C $\substack{A\\B\\D}$ all

C $\substack{A\\B\\D}$ all

DC $\substack{\cancel{A}\\B\\D}$

CAB

BA $\substack{B\\C\\D}$

~~CAB~~, A, C

CD ~~C~~ A

A ~~C~~

CA $\substack{B\\C\\D}$

BC $\substack{\cancel{A}\\B\\D}$

~~ACB~~, A, CCC,

AD, C, A, A

B

CDC

ACB

BAC

DC

~~B~~, A, CAB, A

BAC, A

BCC or BCC

BAD, DAB

~~DAB~~

(BCB + BCD) or (DCD + DCB)

BBC or DDC

BCC or DCC

BAC ~~A, BAB~~,

BAD, DAB,

DAC, DAC CBC

~~C~~DA $\substack{B\\C\\D}$

DAC

BC $\substack{B\\D}$

BBC

BAC

DAC

(13)

no A or all

~~no C no C~~

CBB, CDD ✓

BBB CBB
BDD

DD A, CBB, A
BB C, A

no A or all

no C no C.

BBC, DDC

A, BBC, A, DD
C, DDA, C, BB

A, BBC, A

If Possible code for $A, \overset{\approx}{C}, \overset{\approx}{C}, \overset{\approx}{A}$ (not nec. worse)

obtained by deleting x C x from code for $A, \overset{\approx}{C}, \overset{\approx}{A}$.

A $\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ $\begin{smallmatrix}D\\B\end{smallmatrix}$ BBB DDD $\begin{smallmatrix}A\\B\\D\end{smallmatrix}$AC A$\begin{smallmatrix}B\\D\end{smallmatrix}$C BBC (share B) $= 20$

If all equally represented, what is sum of (A+B) in this class?

Total possible $= 60$.

$2+3+2+3+1+2 = 13$, 12, $2+2+1 = 5$, $2+1 = 3$, 2 $\therefore$ 13, 8, 9, 3, 3 = 36; 13, 12, 5, 3, 2 = 36

Thus 0.6 ... 36 ... .24 ... .52 = 26% if random

Thus altogether $36 + 20$ out of $60 + 20$

$= \frac{56}{80} = 0.7$!!!

.49
.09
.58 = 29% (Fine)

Special sequences: if TT = A.

C A A C
B or D   B or D

recip. A C C A
B or B   B or D.

$\therefore$ only due to overlaps if at all.

$50\overline{)54}$ 675

$\frac{p^2 + (1-p)^2}{2} = p^2 - p + \frac{1}{2}$

$= p(p-1) + \frac{1}{2} = \frac{1}{2} - p(1-p)$

$= 28\%$

675
.675
.325
2025
1350
3375
219375

Can we get $\begin{smallmatrix}C\\B\end{smallmatrix} A A \begin{smallmatrix}C\\B\end{smallmatrix}$

or $\begin{smallmatrix}A\\D\end{smallmatrix} CC \begin{smallmatrix}A\\D\end{smallmatrix}$ a forced chain?

nothing else to these directly.

overlap: $\begin{smallmatrix}C\\B\end{smallmatrix}, A, A \begin{smallmatrix}C\\B\end{smallmatrix} \rightarrow \dots \begin{smallmatrix}C\\B\end{smallmatrix}, A, A B \begin{smallmatrix}D\\B\\C\end{smallmatrix}$

$\begin{smallmatrix}C\\B\end{smallmatrix} A, A, \begin{smallmatrix}C\\B\end{smallmatrix}$ No

Thus only case

$A, CC \begin{smallmatrix}A\\D\end{smallmatrix}$ No

no coding with $B = 7$

$C = \frac{6}{13}$

$DCC, A,$ No.

$= \frac{13 \times 3}{20 \times 20} = \frac{39}{400} = \dots \times 10^{10}$ what now?

is this a ...? or bits the $\frac{39}{400}$?

if $T = B$

$\begin{smallmatrix}D\\A\,or\,C\end{smallmatrix} B B \begin{smallmatrix}D\\A\,or\,C\end{smallmatrix}$ which codes A, BBD

~~nothing codes directly~~

$\begin{smallmatrix}B\\C\,or\,A\end{smallmatrix} DD \begin{smallmatrix}B\\C\,or\,A\end{smallmatrix}$ which ... $ADDB$

choose first line

$\begin{smallmatrix}D\\A\end{smallmatrix} B B \begin{smallmatrix}D\\A\end{smallmatrix}$ no overlap. !! i.e. No

choose 2nd line. $\begin{smallmatrix}D\\C\end{smallmatrix} B B \begin{smallmatrix}D\\C\end{smallmatrix}$

overlaps. do occur

No overlaps

$\begin{smallmatrix}B\\A\end{smallmatrix} DD \begin{smallmatrix}B\\A\end{smallmatrix}$

how common?

Try code

$A_{,} \overset{no}{\underset{\cdot}{c}} \overset{w}{\underset{\cdot}{c}} \overset{no}{\underset{\cdot}{c}}$ ie No C

Thus backward problem does not exist.

Possibles are

- AAAB or AABA or ABAA
- ~~BBABA~~ ABBB
- AAAD or AADA or ADAA
- ADDD
- AABD or ABDA
- AADB or ADBA
- ~~BBAA ADA~~ ADBB
- ABBD
- ADDB
- ABDD

ABAD or ADAB

- ABDB
- ADBD
- AABB or ABBA
- AADD or ADDA = 15

A A C A

C C A

Chan AB in pairs

add BBC ~~BCB~~ ABC BAC ~~ACB~~ AAC ADC

A

A, ABD ABD BDC

ABAD, A, ABD

Try code $A_1 \cdot \overset{w}{A}\ \overset{w}{A}$ high B minim $CC\overset{B}{D}$

$A\,\overset{B}{D}\,\overset{C}{\underset{D}{B}}$ BBB DDD CCC $C\overset{B}{D}C$ $DC\overset{B}{D}$ BBC = 20

A's = 6 B's = 5, 12, 1, 1, 2, 21 A+B = 27

∴ total A+B = $\frac{47}{80}$ = ~ ·6

·36
·16
52

Try my code A_1 ... minimum BBD and DBB

and minimum ACD and BCD

~~ACD~~
ACB

BCB
~~BCD~~

choose BBC

CBC

BBA
BBC

∴ code is $A\,\overset{A}{\underset{D}{B}}\,\overset{D}{B}$ BBB DDD $\overset{A}{\underset{D}{B}}AC$

$A\,\overset{A}{\underset{D}{B}}\,\overset{D}{B}$ $\overset{B}{D}\,D\,\overset{B}{D}$ ~~BBB DDD~~ $\overset{A}{\underset{D}{B}}AC$ $\overset{A}{B}CD$ $A\overset{B}{D}C$ BBC = ~~20~~ 19

BBB DBD

minimum ABB

no of A's = 7, 4, 1, 2, 14 no of B's = 5, 4, 4, 1, 1, 1, 2, 18 14+18 = 32 ∴ $\frac{52}{80}$ = ·65

·65
·35
195
325
2275

∴ 27%

A B B A
D D

C D D C
B B ×

omit

BBD
DBB,
ABB,

21

ABBA
~~ABBD~~
~~DBBA~~
~~DBBD~~

Can one add:

~~AAC ACA CAA CCC~~

(CBB CDD)
BAD DAB
(CAD) ~~DAC~~ (CBC)

ABD
~~B~~
C

D,AC

ACB
D

ACBB   ACDD

BB, ACBB, A
DD, CADD C

, ABAD, ABAD, ABAD ?
, CDCB, CDCB CDCB

omit BBD
DBB
ABB

BB, A, CBB, A, ~~CBB~~
DD, C, A

omit AAB
AAD

BAD ~ DAB

~~[illegible]~~

can ~~see the~~ BB~~A~~?

A, noC . nA

AAB ABA BAA

BBB

AAC ACA CAA CCC

AAD ADA DAA

DDD

—

ABC BCA DCC

ABD BDA

ACB CBA CCD

ADB DBA

ACD CDA CCB

ADC DCA BCC

—

CBB CDD No.

BBC DDC

DBB

BBD

DDB

BDD

BAC CAB CDC

BAD DAB

CAD DAC CBC

~~BCB~~ ~~DCD~~

BDB

DBD

—

ABB BBA

ADD DDA

~~BCD~~ ~~DCB~~

A [illegible] · $\overset{\text{no}}{A}$

Thus we exclude AAC, ABB, ACB, BAC

and try again

	AAB	AAD	ABC	DCC	ADC	BCC	BBC	DDC	BAD	DAB	BCD	DCB	BCB	DCD	
AAB									×						
AAD										×					
ABC				×											
DCC			×								×		×		No
ADC						×									
BCC					×							×		×	No
BBC								×							
DDC							×								
BAD										×					
DAB									×						
BCD				×								×		×	
DCB						×					×		×		
BCB				×								×		×	
DCD						×					×		×		
				No		No									

This one excludes the top one.

Choices for the code A noc . no A

AAB

BBB

✓ AAC

AAD

DDD

—

ABc or DCC

✓ ABD

✓ AcB or ~~CCB~~

✓ ADB

✓ ACD or ~~CCB~~

ADC or BCC

—

—

BBC or DDC

DBB

BBD

DDB

BDD

—

✓ BAC

BAD or DAB

✓ DAC

~~BCB or DCD~~ BCB or DCD

BDB

DBD

—

✓ ABB

✓ ADD

BCD or DCB

—

= 25

Check of the rule of $A^{\text{no } C}_{\cdot} \; \cdot \; \dot{}^{\sim A}$

Forwards	$A \substack{B\\C\\D} \substack{B\\D}$	rejects	$\substack{B\\C\\D} \substack{B\\D} A$	✓
	$A \substack{B\\D} C$	"	$\rightarrow \substack{B\\D} C A$	✓
	$\substack{B\\D} A C$	rejects	$C A \substack{A\\B\\D}$	✓
	$A A \substack{B\\D\\C}$	rejects	$\substack{B\\D\\C} A \substack{A\\B\\D}$	✓ [illegible]
Backwards	$\substack{A\\B} C \substack{B\\D}$	reject	$\substack{C\\D} C \substack{A\\B\\D}$	✓ DCB DCD
	$\substack{A\\B\\D} A C$	"	$C \substack{C\\B\\D} C$	✓
	$A \substack{B\\D} C$	"	$\substack{B\\D} C C$	✓
	$B B C$	"	$D D C$	✓ o.k.

Codes with A, B only:

AAAB

BBBA

AABB = 3

AB and C only. [ie no D]

Above 3 plus

only one x without B

AAAC
ACCC

BCCC

BBBC

AABC

AACB

BACC

ABCC

BBAC

BBCA

ABAC

BCAC

BABC

BBCC = 16 in all

A B and D [no C]

24

−7
−4
−1
−1
−1

24 −14 = 10

24

−2
−3
−2
−1
−2

24 −10 = 14

Total single pyrimidines is 9·1%

A, B ~ Purine, Pyrimidine

$2{\cdot}45\%$ $\frac{2{\cdot}45}{11{\cdot}5}$!

Thus try ,AABBB, AABBB, and ,ABBBB, ABBBB,

2·5% 9·1%

Try ,ABBBA, and ,ABBBB,

assume roughly equal amounts.

∴ 3 and 4 fragments amount to ~ 10 %

if two sorts at random

$① = p \quad ② = 1-p$

		A	AA	A	AA
Then	① + ②	–	1		$p(1-p)$
	① + ①	–	1		p^2
	② + ①	1	–	$(1-p)p$	
	② + ②	1	–	$(1-p)^2$	
				$(1-p)$	p

Prob. argument not necessary as

$A \sim 9{\cdot}1$

$AA \sim 2{\cdot}6$

$11{\cdot}7$

$\therefore p \sim \frac{2{\cdot}6}{11{\cdot}7} = 22\%$

Say $p \sim \frac{1}{4}$ or $\frac{1}{5}$ above

but this doesn't fit with roughly equal amount assumed earlier.

$\frac{p-p^2}{1-p}$

11·7 | 260 | 22

How to characterize a sequence of 2 things?

0①000①0⑪0①0①0⑪0⑪0111100101011111

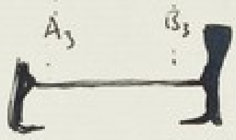
A + B.

no of 1's
no of 2's
no of 3's

p ^ A_1 B_1

A_2 B_2

A_3 B_3



$P_y\ {}^{1}P_u^{0}\ P_u^{0}\ P_u^{0}\ P_u^{1}\ P_y$

28.4% Thymine
21.2% Cytosine

$Pu_n\ (n-1)$

Let there be n purines in m fragments
then total release of phosphate $= (n - m)$

Thus for 28% P release and 50% ~~[illegible]~~ purines

$$\therefore \quad \frac{N\,(50-28)}{100} = N.\frac{22}{100} = \text{total no of purine fragments}$$

pCp	= 3·6	3·6
pTp	= 5·5	5·5
$pCpTp$	1·95	3·9
$pCpCp$	0·5	1·0
TT	0	
	11·55%	14·0%

Thus 36% in higher ones
in fragments $22 - 11\frac{1}{2} = 10\frac{1}{2}\%$

Thus average chain length of remaining fragments is $\frac{36}{10\frac{1}{2}} \approx 3\frac{1}{2}$

Thus some must be shorter than 3.

if mixture of 3 and 4, about equal amount

35

Try again ABBBB and AABBB

or BBBBA and AABBB no diff

Thus difference in these lines AA is coupled to higher BBB

Try ABBB BA

~~Syllable code~~ A ~ C

B ~ D

~~Code with A and B only is~~

~ A B C if random.

~ C D A

A ~ C

B

C ~ A

B ~ D

B ~ D

B ~ D

Thus ~ 75% to 25%

Thus try a ~~four letter~~ or four gap code with 3 letters ~~one~~ on one chain.

$\frac{3}{4}$ $\frac{9}{16}$

$\frac{1}{4}$ $\frac{1}{16}$

$\frac{10}{16}$ ∴ $\frac{5}{16}$ ~31%

16) 500

48

20

16

40

1st chain

A ↔ C
B ↔ D

2nd chain

DADB	ADCC	DBCB	AABC
BABD	BDCC	BDCD	AABD
DABD	DACC	BDCB	AACB
BADD ✓	DBCC	BBCD	AADB
DABB	BACC	DDCB	AACD
BADB	ABCC	DBCD	AADC
DADD	BBCC	BBCB	AADD
BABB	DDCC	DDCD	AABB

ACAB	(DCAC)
ACAD	(BCAC)
BCAB	(DCAD)
BACB	(DACD)
~~BADA~~	~~(CBCD)~~
CBCD	(BADA)
CDCB	(DADA)

2nd chain

~~AAAB~~
~~AABC~~
~~AABD~~

CADA BBAC
AADA BBCA
CCDC

[illegible] C in [illegible]

~~BBAC~~
~~AACD~~
~~BBCA~~

Dont begin with C
Dont end with A

Code	A	B	C	D
20	18	23	20	19

[illegible]
24
22

Sol.

Ser, glycine
are abolished by
pure Fl-Phe.
probably not chambers,

intact cell:

inhibitor for RNA
stopped enzyme synthesis.

also depletion effects.

Protoplasts.

removal of all DNA leaves
its enzyme-forming ability.

All	in chain 1 with which with	in chain 2
AAAB (DCCC)	none.	the with 7 to give BDCC with 7 to g DDCC
BBBA (CDDD)	BABD with BDCC and BADD with DDCC BABB " BBCC BADB DBCC	ABCC with [ABCC] ABCC with [ADCC]
AAAC (ACCC)	none.	with 7 to give BACC with 7 to give DACC
AAAD (BCCC) BCCC	none.	with 7 — BBCC with 7 — DBCC
~~AABA~~ ABAA (CCDC)	no	for BDCC, with (BDCC) give BDCC with (DDCC) give BBCC with (BBCC) give (DDCC) with (DBCC) give (DBCC)

CDCC

BBBD
BDDD

~~BBAD~~ BB.BD | BBBD . BDDD | ~~BDBD~~ ~~BD~~ ditto
BB.DB | BBDB . DBDD | ditto
BD.BB | BDBB . DDBD | ditto
DB.BB | DBBB . DDDB | ditto

ABCD
BADC

? AABC.D | ABCD . BADC | B.ADCC ?
D.ABCC | DABC . ~~CBAD~~ ADCB | AADC.B ??
CC.DAB | CDAB . DCBA | BDCB.AA
BBCD.AA | BCDA . CBAD | BACB.ADCC

?

BBCA
CADD

B.BCAB | BBCA . CADD | ACAD.D
BCAB . DCAD
CABB . DDCA
ABBC . ADDC

ABAD
BCDC

BCAB.ADCC | ABAD . BCDC | AABC.DCAD
AADC.CBCD | BADA . CBCD | ~~BADA.ABCC~~ — ?
ACAD.ABCC | ADAB . DCBC | AADC.BCAC
AADC.CBCD | DABA . CDCB | ~~[illegible]~~ — ?

BABC
ADCD

B.ABCC | BABC . ADCD | * AADC.D
AABC.B | ABCB . DADC | D.ADCC
DBCB.AABC | BCBA . CDAD | ADCC.BADB
BACB.ABCC | CBAB . DCDA | AADCBACD

AcAB (DCAC)
✓ 3. ADCC (AABC)
✓✓ 3. ABCC (AADC)
BACB (DACB)
✓ BCAB (BCAD)
~~ACAD (BCAC)~~

A ⟷ C
B ⟶ D

20 cycle

Check if any more can be added.

Switch groups not used

AAAB } DCCC

AAAC } ACCC

AAAD } BCCC

BBBD } BDDD

ABCD } BADC

~~BBCA~~ } ~~CADD~~

ABAD } BCDC

BABC } ADCD

AAAB } DCCC

AAAB DCCC
AABA CDCC
ABAA CCDC
BAAA CCCD

		1st ch	2nd ch
AAAB (DCCC)	B.DCCC	×	×
AABA.(CDCC)	AABA.DB..	×	×
ABAA.(CCDC)	BD.CCDC	×	×
BAAA.(CCCD)	BD.CCCD	×	×

∴ cannot occur

omit

	forward			reverse
AAAC ACCC	B.ACCC	AAAC	ACCC	ditto
	AACA.B	AACA	CACC	ditto
	BD.CCAC	ACAA	CCAC	ditto
	BD.CCCA	CAAA	CCCA	ditto

AAAD } BCCC	D.BCCC	AAAD	BCCC	ditto
	AADA.BD	AADA	CBCC	ditto
	BD.CCBC	ADAA	CCBC	ditto
	BD.CCBC	DAAA	CCCB	ditto

omit

ACAB (DCAC)

~~ACDC~~

~~ABAC (ACDC)~~

ACAD (BCAC)

BCAB (DCAD)

~~BCAD~~

ACAB, ACAD, ACAB, ACAD,

DCAC, BCAC, DCAC, BCAC,

~~ABAD~~ (BCDC)

ACAB (DCAC)

ACAD (BCAC)

BCAB (DCAD)

BACB (DACD)

ACCC (AAAC)

BCCC (AAAD)

DCCC (AAAB)

B
D. ACCC.

D
B. BCCC

D
B. DCCC

DADB BDCC

BABD DBCC

DABD BACC

BADD ABCC

DADD BBCC

BABB DDCC

CBCA ACDD

~~ABAC~~ CADD

CBCC

ABAA

DABB ADCC

BADB DACC

ABAC,A . . .

A.BACC

ABAC.DDCC

CBCA,DDCC

ACAB ✓ (DCAC) ACAD (BCAC)
ABAC (ACDC) ADAC (ACBC)

ACBC (ADAC) ACDC ✓ (ABAC)
BCAC (ACAD) DCAC (ACAB)

BACB (DACD) DACD (BACB)

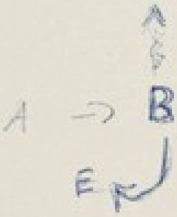
BCAB (DCAD) DCAD (BCAB)

ACCC (AAAC)

BCCC (AAAD)

DCCC (AAAB)

ABAD (BCDC) ADAB (DCBC)


A
B
E

Solution

Altered

ABAB / C / D (DCDC / A / B)

ABAB / D

✓ ABAC (ACDC)

~~ABAD (BCDC)~~

✓ ABAD (BCDC)

ABBB / C / D (DDDC / A / B)

ABBB / C / D

~~ABBC (ADDC)~~

~~D. ABBC (ADDC)~~

ABCB / C / D (DADC / A / B)

ABCB / C - [illegible] / D

ABDB / C / D (DBDC / A / B)

ABDB / C / D

ADAB (DCBC)

✓ ADAC (ACBC)

ADAB / C / D (DCBC / A / B)

ADAB / D

ADCB / C / D (DABC / A / B)

ADCB / C (End) / D

B ... D

BAA B / C / D

BAAB / (C) - [illegible] / D

BAB B / C / D

BABB - [illegible] / C / D [illegible]

BACB / C / D (DACD / A / B)

BAC / C / D

✓ BACB (DACD)

~~BACD (BACD)~~

BADB / C / D

BADB [illegible] / C / D [illegible]

. . . A   C . . .   Forbidden   Allowed

Try

A . . .   (. . . C)   forbidden $A\begin{smallmatrix}B\\D\end{smallmatrix}\begin{smallmatrix}B\\D\end{smallmatrix}\begin{smallmatrix}A\\B\\D\end{smallmatrix}$

AC . .   (. . AC)   o.k.

$ACA\begin{smallmatrix}B\\C\\D\end{smallmatrix}$

$ACA\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}CAC\right)$ forbidden $ACA\begin{smallmatrix}A\\C\end{smallmatrix}$ ✓ ACAB (DCAC)

✓ {ACAD (BCAC)

$-ACB\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}DAC\right)$ $ACB\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ depends on DACC (AACB)   ✓ ACBC (ADAC)

$ACC\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}AAC\right)$ $ACC\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ depends on (DACC) & (BACC)   ✓ ACCC (AAAC)

$ACD\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}BAC\right)$ $ACD\begin{smallmatrix}A\\B\\D\end{smallmatrix}$ ✓ ACDC (ABAC)

AA . .   (. . CC)   o.k.

$AAA\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}CCC\right)$ $AAA\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}$

$AAB\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}DCC\right)$ $AAB\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix}$

$AAC\begin{smallmatrix}B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}D\\A\\B\end{smallmatrix}ACC\right)$ $AAC\begin{smallmatrix}B\\C\\D\end{smallmatrix}$ ours

$AAD\begin{smallmatrix}B\\C\\D\end{smallmatrix}\left(\begin{smallmatrix}D\\A\\B\end{smallmatrix}BCC\right)$ $AAD\begin{smallmatrix}B\\C\\D\end{smallmatrix}$

BACB

DACD

BB . .

forbidden ~~BB~~ BBC B D

BB A B D B D

BB A B B D C D

partly due to DDCC (AADD)

BB A B C C D (A C D DD A B)

BBBC A C D

all forbidden

BC B B D D

BC . .

BC A A B C D

~~BC~~

BC A C B

BCC B

✓ BCAB (DCAD)

BCAB (DCAD)

BC A C D (BCAD)

BCAD C

BC A B C C D (A C D A D A B)

BCBC D

✓ BCAC (ACAD)

✓ BCCC (AAAD)

BDAB C D

BDAB (C) -wich. D

BDBB C D

BDBB C D

BDCB C D

BDCB C D

BDDB C D

BDDB (C) -wich. D

× CBCA	[BCDD]
× ABAC	ACDD ×
CBAC	[CBDD]
~~ABCC~~	CADD ×
[CBAA]	ABDD
[ABCA]	~~BADD~~
× CBCC	~~AADD~~
× ABAA	CCDD
hoDs.	hoDs

DADB

CADA, DBCB

AADA. d.h.

DA. DD

DA DD
DA. BB.

DA
[illegible]

AABD, CCDC

[illegible]

AABC
CCDA
ADCC

AABD
CCDB
BDCC

AACB
CCAD
DACC

AADB
CCBD
DBCC

AACD
CCAB
BACC

AADC
CCBA
ABCC

BBAC
DDCA
ACDD

BBCA
DDAC
CADD

BBAD
DDCB
BCDD

BBDA
DDBC
CBDD

BBCD
DDAB
BADD

BBDC
DDBA
ABDD

~~CCAB~~
~~AACD~~
~~DCAA~~

ABAC
CDCA
ACDC

ABAD
CDCB
BCDC

~~ACAB~~
~~BDCD~~
~~DCBA~~

ACAD
CACB
BCAC

BABC
DCDA
ADCD

BABD
DCDB
BDCD

BCBD
DADB
BDAD

ABCD
CDAB
BADC

ABDC
CDBA
ABDC

ACBD
CADB
BDAC

ACDB
CABD
DBAC

ADBC
CBDA
ADBC

ABC

8,1	8,1	8,1	8,1
4,1	8,1	8,1	8,1
4,1	8,1	8,1	8,1
4,1	8,1	8,1	8,1
4,1	8,1	8,1	8,1
	8,1	8,1	8,1

256
86
168
21

10

BACA

4,3,2,
24

ABDC ABDC
CDBA CDBA

ACBD ACBD
CADB CADB
BDAC BDAC

A↔C
B↔D

BCAA

ADBD CA ADCC
ABDB CA BDCC
ABDD CA DACC
ADDB CA DBCC
ABBD CA BACC
ADBB CA ABCC
ADDD CA BBCC
ABBB ~~CAAD~~
CA DDCC

CBDB BDBC AABC
CDBD DBDC AABD
CBBB BBDC AACB
CBBD DBBC AADB
CDDB BDDC AACD
CBDD DDBC AADC
CBBB BBBC AADD
CDDD DDDC AABB

DADB ADCC
BABD BDCC
DABD DACC
BADD DBCC
DABB BACC
BADB ABCC
DADD BBCC
BABB DDCC

DBCB AABC
BDCD AABD
BDCB
BBCD AACB
DDCB AADB
DBCD AACD
BBCB AADC
DDCD AADD
AABB

ADD DACD

BDCC
ABCD
C A
BACB A
CBBA AAAD
CBDA AACC
CDDA
CDBA

CDDA
CDBA
CBBA
CDBA

DAA B
C
D

DAAB
C
D

DABB
C
D

DABB on
C
D on

DACB - (DACB
C A
D - B)

DAC B
C on

√DACD (BACB)

DADB
C
D

DADB on
C
D on

DBAB
C
D

DBAB
C
D

DBBB
C
D

DBBB
C
D

DBCB
C
D

DBCB on
C on
D -

11

DBDB
C
D

DBDB
C
D

DCAB - (DCAB
C - A
D B)

DCAB

√DCAC (ACAB)
√DCAD (BCAB)

DCBB (ADAB)
C -
D

DCBB
C
D

√DCCB (AAAB)

DCCB
C - (AAAB)
D

DCCB
D

DCDB
C
D

DCDB
C
D

OVER (see what we only)

BCDA

DABC

CBAD

DDA B
C ~
D

DDA B
(C) [illegible])
D

~~DDAC (ACBD)~~

DBB B
C
D

DDB B
C ~
D

DDC B
C
D

DDCB [illegible]
C [illegible]
D

DDD B
C
D

DDD B
C
D

Class	total no.		no. possible	self [illegible]	↓
AAAA		4	0		0
AAAB	(6x8)	48	6		6
ABAB	(2x[illegible])	12	0		0
AABB	(2x(8+4))	24	4	− 2	2
AABC	(12x8)	96	12		12
ABAC	(6x8)	48	6		6
ABCD	($\overset{8}{[illegible]}$)	24	~~5~~		1
			33 ~~[illegible]~~	= 29	27

33
8
264
2

(ABAC)

A ⇔ C
B ⇒ D

AAAB
CCCD
DCCC

BBBA
DDDC
CDDD

AAAC
CCCA
ACCC

AAAD
CCCB
BCCC

BBBC
DDDA
ADDD

BBBD
DDDB
BDDD

ABAB
CDCD
DCDC

ACAC
CACA
ACAC

~~ADAD~~
~~CBCB~~
~~BCBC~~

~~BDBD~~
~~DBDB~~
~~BDBD~~

AABB
CCDD
DDCC

~~AACC~~
~~CCAA~~
~~AACC~~

AADD
CCBB
BBCC

~~BBDD~~
~~DDBB~~
~~BBDD~~

8, 1
8, 1
8, 1
8, 1
8, 1
8, 1

4, 0
2, 0
4, 0
2, 0

~~870~~ 8, 1
4, 1
8, 1
4, 1

	AA	AB	AC	AD	BA	BB	BC	BD	CA	CB	CC	CD	DA	DB	DC	DD
AA	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
AB	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
AC	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
AD	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
BA	/	/	/	/	/	/	/	/	1/2	/	/	/	/	/	/	/
BB	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
BC	/	/	1/2	/	/	/	/	/		/	/	/	/	/	/	/
BD	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
CA	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
CB	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
CC	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
CD	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
DA	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
DB	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
DC	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
DD	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

$\left| A\ B\ \begin{matrix}A\\B\end{matrix} \right|$ $\left| \begin{matrix}A\\B\end{matrix}\ C\ \begin{matrix}A\\B\\C\end{matrix} \right|$ $\left| \begin{matrix}A\\B\\C\end{matrix}\ D\ \begin{matrix}A\\B\\C\\D\end{matrix} \right|$

Brush one side of
B and C

ACB, BDA, CDB, BCA, BDC, ACB, ABB, ADA, ACC,

ADD

B
C

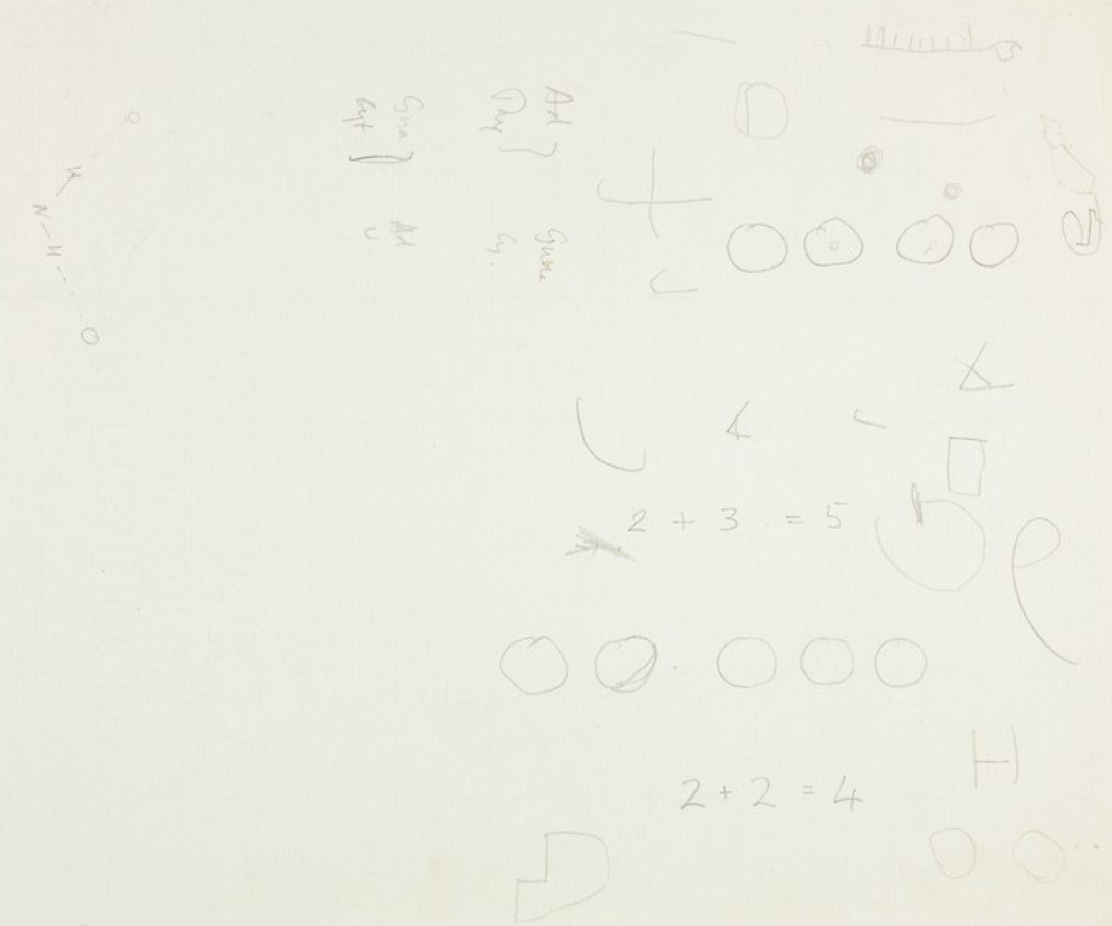
select A - game

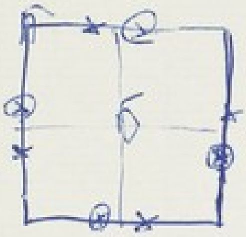
ABA - b
ABB - c
ACA - d
ACB - f
ACC - g
BCA - h
BCB - j
BCC - ~~j~~k
ADA - l
ADB - m
ADC - n
ADD - p
BDA - q
BDB - r
BDC - s
BDD - t
CDA - v
CDB - w
CDC - x
CDD - y

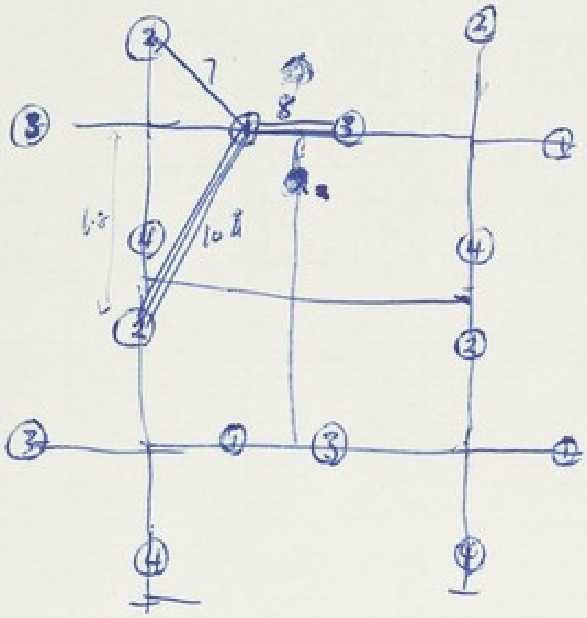
ADC, ADB, ADA, ACB, BDB, ADB, BDB, CBD, BDC, ADD, BDB, ADD, BDB, ADC, BDC,

BDD, BDB, ADC, BDC, ACB, BDB, ADB, ACA, ABA, CDD, ABB, BDD, ADC,

A 1 1
D 3 2


2 + 3 = 5
2 + 2 = 4





11.3
4.5
6.8

4.2
6
6.2

11.3
9.0
2.3

6.8

$\left[\begin{array}{l} A \leftrightarrow C \\ B \leftrightarrow D \end{array}\right]$

Assume code is
$$\begin{array}{ccc} & A & \\ A & B & C \\ B & C & D \\ & D & \end{array} \quad \text{plus} \quad \begin{array}{c} AAB \\ BBA \end{array} \quad \text{and} \quad \begin{array}{c} DCC \\ CDD \end{array}$$

① no restriction on # neighbours of these 16

② forbidden for AAB or (BBA): anything, AAB or (BBA),

ACC / BDD	= 8
BA^C_D or (AB^C_D)	= 2
DCC / CDD	= 2
	12

③ forbidden for DCC or (CDD): AAC / BBD, DCC or (CDD), anything

AAC / BBD, DCC or (CDD), anything	= 8
$^A_B CD$ or $(^A_B DC)$	= 2
AAB / BBA	= 2
	12

ie only 6 [illegible] are allowed on one side.
(+2 same ones)

Assume code is $\begin{matrix} & A & \\ A & B & C \\ B & C & D \\ & D & \end{matrix}$ plus AAB and CCD
BBA DDC

Then (1) no restriction on neighbours of the 16

~~(2) of the four the two pairs can neighbour each other~~

(2) forbidden for AAB or BBA are anything, AAB or BBA, nor $\begin{matrix} A & C & C \\ B & D & D \end{matrix}$ = 8

nor $BA\begin{matrix} C \\ D \end{matrix}$ or $AB\begin{matrix} C \\ D \end{matrix}$ = 2

nor $\begin{matrix} CCD \\ DDC \end{matrix}$ + 2

~~10~~ 12

(3) forbidden for CCD or DCC are $\begin{matrix} A & A & C \\ B & B & D \end{matrix}$ CCD or DCC, anything

nor $\begin{matrix} A \\ B \end{matrix}DD$

$\begin{matrix} A \\ B \end{matrix}CC$

nor AAB
BBA

BBA

A
A B C
B C D AAB A B C
B C D
D

A

BA $^{C}_{D}$

CCD DDC

A → C
B → D

B $^{A\,C}_{B\,D}$

A
A B C CCD A A C
B C D. B B D
D.

BBA

CCD
AAB

A $^{C}_{D}$ C
B

~~DDC~~

A

DDC

B I

A
A B C DCC
B C D
D

A C C D
B

A
A B ~~C~~ DCC
B C D
D

A C D D
B

Leu
Val
Glu
Ile
(Asp)

A C C
B D D

A C ^{C}
B

A
B

A C C
B

A A C
B B D

A D C
B D

B B $^{C}_{D}$

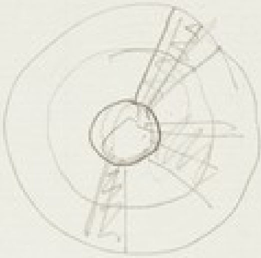
AAACAAAC

AABCAABC

~~ABACABAC~~

~~BACABA~~

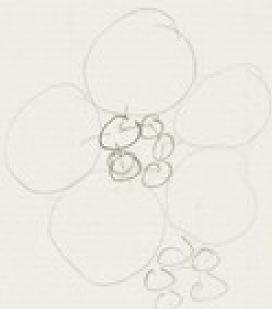
Reichweite : 7 ah



CCD AB

A
A B C
B C D
D

C A A
D B B
C
D



AAB
BBA

CCD
DCC

AAB } 4+2
BBA }

CCD } 4+0
DCC }

AABAAB 4+2

A
A B C
B C D
D AAB B C D
A
B C
D

B A C
B D

A C
B D

-4

DAABCCD
ABC
BCC

CCD.AAB

AAB/DCC

A
A B C C C D
B C D

A C
B D

A B A B | A B C A B C | A B C D A B C D

ABCD

1 A-B C-D
2 A-C B-D
3 A-D B-C

(1) BA A B | A B D A B D | A B D C A B C D

reversed

A B A B | A B D D A B | A B C D C A B D

A B C A B | A B D A B

(2) C D C D | C D A A C D | A C D B A B C D

reversed

C D D C | A C D A C D | A B C D B A C D

DAC, AAD, BBC, A

not

. AB | C . .

. AB | D . .

. AC | D . .

. BC | D . .

(3) D C C D | C D B B C D A | B C D A A B C D

reversed

C D C D | B C D B B C D | A B C D A B C D

A → B
C → D

not ABC
ABD 12
ACD

not BCD 8

run

AAA

ABB AAB

BBA

BDA

CDD CCD

ABDA

A B C

4

MYERS

17 Bant Rd. Letters

R.H. Locker C-Terminal Groups in Myosin, Tropomyosin, Actin.

B. et B. Acta (1954) 14 533

Tropomyosin. C terminal sequence Ileu. Ser. Thr. Met. Ileu. Ala....

Actin . . . . Phe. Ileu. His.

Myosin — at least one Ileu

R. Acher + J. Chauvet. Structure de la vasopressine de boeuf.

B. et B. Acta (1954) 14

Cys. Tyr - Phe. GluN. AspN. Cys Pro Arg Gly-NH₂

R. Acher et al. Étude des peptides de la phenylalanine resultant de l'hydrolyse acide et enzymatique du lysozyme. letter

B. et B. Acta (1954) 14, 151

Val Phe

Lys Val Phe

Phe Asp?

Ser Phe Asp? Phe Glu?

Val Phe. Gly Arg

Adrienne Thompson : Amino acid sequences in Lysozyme.

B. et B. Acta. (1954) 14, 58, letter.

N term. Lys Val Phe Gly

Anfinsen et al: Arg His. Lys. / Tyr. Gly / Gly. Tyr

Ser. Asp? ~~Gly~~, Met. Asp?

Thr. Asp? Val. Glu? Ala – Dash?

Ileu Glu? Leu Ala Leu

Thr. Glu? Ala

Asp? Glu? Ala

Leu. Thr. Ala

Ala Met Lys. Cys. Arg

Gly. Phe. Glu? Asp? Ileu

Thr. Pro. Gly.

---

and	Ala. Ala	Cys Ala	Ileu. Asp	Ser Ala
	Ala. Lys	Cys. Asp	Ileu. Arg	Ser Arg
	Asp? Ala	Cys Lys	Ileu. Val	Ser Leu
	Asp? Arg	Gly. Leu	Leu. ~~I~~Leu	Ser Val
	Asp? Leu	Gly. Lys	Phe. Asp?	Thr. Gly.
	Arg. Asp?			
	Arg Leu			

x s

To AAB add ABA
y t
BBA [illegible] BAB

	x	y	s	t
x	×	✓	×	×
y	✓	×	×	×
s	✓	×	×	×
t	×	✓	×	×

end unit AAA
BBB
~~[illegible]~~
[illegible] unit CCC
DDD

	x	y	s	t
x	s			
y				
s				
t				

Are AAB
BBA

A C A A C A A C A
B D B B D B B D B
C C C CCD AAA
D D D

end chain

CCD
DDC Rate.

10

2

each forbidden ~~two~~ neighbours
(~~two the same, two different~~)
[illegible] can neighbour each other.

add on one side
[illegible]

failures
[illegible]

AAB - CCD
- DDC

BBA - CCD
- DDC

ADD - CCD
BDD -

ACC - DDC
BCC

8

change A→B
C→D

the code still ok,
[illegible] different

Add AAB
BBA

CCC
DDD

CCC - CCC
DDD - DDD

ACC - CCC
BCC -

ADD - DDD
BDD -

~~[illegible]~~

[illegible] chain unit CCCC

AC
BD C - CCC = 4

AC
BD D - DDD = 4

[illegible] A
[illegible] B -

A
A B C
B C D
D

A↔C
B↔D

AAB DCC

CCD

AAB (mir Sohn ... $\begin{smallmatrix}B & C\\A & D\end{smallmatrix}$) B^{CC}_{DD} A) 8 DCC, CDD

DCC (mir ... $\begin{smallmatrix}A & A & C\\B & B & D\end{smallmatrix}$) 8 AAB, BBA

$B^{C}_{D}{}^{C}_{D}$

BBA

CDD

Cys Lys
Cys (Asp)
Cys Ala

Cys, Met, Try, Hist.

Leu Cys Gly	GluN His Leu
Val Cys Gly	Ser His Leu
GluN Cys Cys	Glu His Phe
Cys Cys Ala	
Cys Cys Thr	
Val Cys Ser	
Isol Cys Ser	Ser Met Glu
[— Cys Tyr]	Thr Met Ileu
[Asp Cys Pro]	Ala Met Lys
	Gly Met [Asp]

CysCys

Arg Try Gly

B A C A
D C D B

BACA
BDCD

AACC
BBDD

BBAA
BDBD

AAAB

A C A B
B D C D

Insulin

NH₂ NH₂ +

B. Phe. Val. Asp. Glu. His. Leu (CyS-) Gly. Ser. His. Leu. Val. Glu. Ala. Leu. Tyr.

30 Leu. Val. (CyS-) Gly. Glu. Arg. Gly. Phe. Phe. Tyr. Thr. Pro. Lys. Ala.

Ala Gly - Val

21 A. Gly - Isol - Val - Glu - Glu - (CyS) - (Cys) - Ala - Ser - Val - (Cys) - Ser - Leu - Tyr - Glu - Leu - Glu - Asp - Tyr - (Cys) - Asp

Thr - Ser - Isol

N term

β-corticotropin: Ser. Tyr. Ser. Met. Glu. His. Phe. Arg. Try. Gly - Lys. - Pro - Val - Gly. - Lys

pig - Lys - Arg - Arg - Pro - Val - Lys - Val - Tyr. Pro - Ala - (Gly. Glu Asp) Asp . Glu - Leu

Ala - Glu - Ala - Phe - Pro - Leu - Glu - Phe

36 ...

87+3

A A
D B B
C

original code.

A A
D

ADD D
DAA D

~~DAD~~

A B B C C D
B A C C B D D
C D D
D

B A A A A
C C D
D D

A → D
B
~~B~~ C
C

finishes with
AAAAA . .
starts with DDDDD

A – D
B – C

DD

A ↔ D
B ↔ C

A A
D C B
B C
D

A A D
D A D

A B A
D B
D

ADD
DAA

~~AAD~~

AAAA

Backwards

A ↔ B
C ↔ D

2
A B
B A C
C D
D

D

the general solution
for n, taken three at
a time

n	2	3	4	5
	A B $\begin{matrix}A\\B\end{matrix}$	$\begin{matrix}A\\B\end{matrix}$ C $\begin{matrix}A\\B\\C\end{matrix}$	$\begin{matrix}A\\B\\C\end{matrix}$ D $\begin{matrix}A\\B\\C\\D\end{matrix}$	$\begin{matrix}A\\B\\C\\D\end{matrix}$ E $\begin{matrix}A\\B\\C\\D\\E\end{matrix}$
	1.2.	2.3.	3.4	4.5	5.6
	$\frac{2}{}$	$\frac{6}{}$	$\frac{12}{}$	$\frac{20}{}$	$\frac{30}{}$
	2	8	20	40	70
=	2	8	20	40	70

~~AB~~ AAA –
AAB
ABC

$$\frac{n^3 - n}{3}$$

$$\frac{n(n^2-1)}{3}$$

$$\frac{(n-1)(n)(n+1)}{3}$$

~~$(n+1)(n+1)$~~

$$\frac{(n-1)(n)(n+1) - (n-2)(n-1)(n)}{3}$$

$$= \frac{(n-1)(n)(n+1-n+2)}{3} = n(n-1)$$

2.3.4 3.4.5 4.5.6 5.6.7

A ↔ D
B ↔ C

A B C D / D / A B C

A B C / C / A B

A B / B A

A C
B D

A
B A C
C B D
D

C C D
C D D

AAB
BAB
CAB
DAB

ABD
ABC

C C D
D C D

CAC CBD DACDCD BABBBDDACCCD
BDB BCAADBABA,CDC,CCAADBBBA
← ← ← ← ←

A ↔ B
C ↔ D

A C
C A D
D

A
B B C
C D
D

C D C
D

A C A B
B D B C
C D
D

A ↔ D
B ↔ C

A ↔ C
B ↔ D

A D D
B D B
B C A
A D B
A B A
C D C
C C A
A D B
B B A

A.. A
D × D

B A B
C
D
A A B
C
D

A
A B C
C D
B D

we never get AA

nor AA

AB A B C D

AC "

AD "

BA A B C D

BB A B C D

BC A B C D

BD A B C D

CA A B C D

CB A B C D

CC A B C D

CD A B C D

DA A B C D

DB A B C D

DC A B C D

DD A B C

— nor DDD

A A
D B
C C
D D

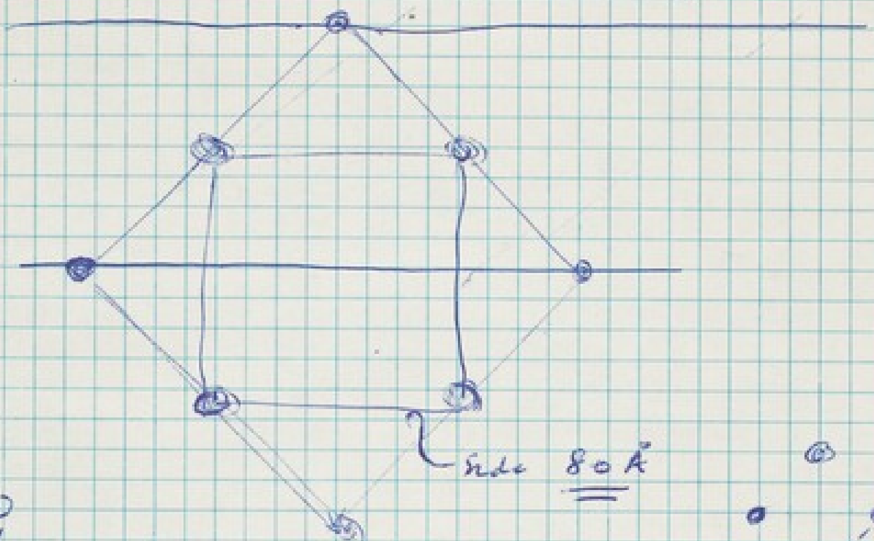
A B C D

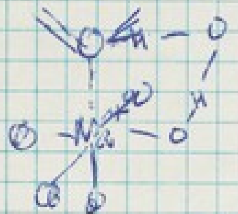
A C A
D C D

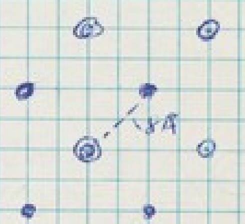
D A D
A A

density $= \dfrac{349 \times 4}{973 \times 6.03 \times 10^{23} \times 10^{-24}}$

?2







Density   mw ≈ 300 ?

Suppose cell 8 Å side

$8^2 \times 15.2$

			mass
mw	N	5	70
	C	5+5	120
	H	2+7	9
	O	6	96
	P	1	31
	Na	1	23
			349

$$\begin{array}{r} 15.2 \\ 64 \\ \hline 912 \\ 608 \\ \hline 9728 \end{array}$$

973 Å^3

ABC Form [illegible] [illegible] [illegible]

AB
BC
~~BA~~
CA

$3^4 = 81$ possibilities

Class	Total	[illegible]
AAAA	3	0
ABBB	24	6
AABB	12	3
ABAB	6	3
AABC	24	6
ABAC	12	3
	81	21

18

16

$2^4 \times 3$ 48

3.2 9

ABCA
BC

4

AABB
BB CC
CC AA

ABAB 42
BABA 24
66 81
3.2 69
3.2 12

AA BB

AA CC
BB
C

C AAA
BBB

AABB
ABBA
BBAA
BAAB

ABAC
BACA
ACAB
CABA

ABAB
BABA

2 ABCD

A B C A
B C A B

A B C A
B C A B

AB BA

AA
A 6.

AB ~~BA~~
AC ~~CA~~
~~BA AB~~
BC ~~CB~~
AD ~~DA~~
BD ~~DB~~
CD DC

AB
AC
AD

BC
BD

AB ~~AB~~ BC
AC BC
AD ~~DA~~
DC
DB
BC

A·

A C A
D   C
    D   6

A B A
D   B
    C
    D   8

C B A
    B
    C
    D   4

B

ADD
DAA

B – D

A C A
B D B
    C

A DD
B

CD A
    B
    C
    D

ABB
BAA ✓

A C D
B

no
B

no   B
B

or less
one B

A B A
D   B
C   C
    D   12

A B A
D   B
C   C
    D

no   C
C

or less one C
no B

A C A
D   C
    D   6

no B or C

ADD
DAA   2

20

AAAA   no less
DDDD   to end
chm.

BDBD   one A
CCCC   begin ch.

CB

DADA

A BB   2
D

A B A   12
D C C
      D

C B A   4
    B
    C
    D

ADD   2
DAA

[illegible] code

AB^2	ABA	ABC -
AC^2	ACA .	ABD . -
AD^2	DBD	ACD -
CB^2	DCD	CBD
DA^2	CBC	DBC -
DB^2		CBA
DC^2		DBA -
		DCA -

[illegible]

BBB
CCCC
~~AAAA~~
DDDD

[illegible]: A D

[illegible]? B 15

C 15

A C
DB B
D

A
DC C
D

ACA, CBB, DBC

ACA CBB DBC

ABB
ABA
C
D

A
ACC
D

ACA, ACA, ACA

64

ACC
ACD
ACA

AAA 60
40

A C A

A C
CB B
D

A
AB B
C
D

not
B

A A
B B B
C C C
D

Triples

Basic code: $\left.\begin{matrix} A & C & A \\ B & D & B \\ & & C \\ & & D \end{matrix}\right\}$ — 16

To this add. AAB and BBA = 18

all can neighbour all.

Now suppose we add CCD and DDC — suppressed here.

Note that we can have any combination of these last two

Forbidden neighbours are anything of the form
.. A . CCD
.. B . CCD
.. A . DDC
.. B . DDC

Thus CCD has 8+2 = 10 neighbours on one side forbidden

ditto DDC

If these two are tryptophan & methionine, we can lump neighbours to test this.

Some sequences which never occur:
pairs: all occur & main
~~any~~ triplets: all occur
these ~~CC~~
$\left.\begin{matrix} CDC \\ DCD \\ CDD \\ DCC \\ DDC \\ CCD \end{matrix}\right\}$
especially in plant?

To end chain have
AAAAA...
or BBBBB...

To start chain, we
-- CCCCCC 2
.. DDDDDD

No restriction on first or last amino acids in a chain

Thr. Met. Ileu. B Tropomyosin.
Ala Met. Lys ~~Trop~~ Lysozyme.
Arg Try. Gly β-lactoglobulin..
Ser Met Glu "

Sets of Four

Try

A	C	A	B	A	C	A	B
B	D	C	D	B	D	C	D

[illegible]

must ADAD
~~[illegible]~~

A A C C
B B D D

A	B	C	C
		D	D

A B C A
    D B
      C
      D

$$\begin{array}{ccc} & A & \\ A & B & C \\ B & C & D \\ & D & \end{array}$$

~~we can add AAB~~

and ~~BBA~~

$$\cancel{A}\cancel{AB}\;\begin{array}{ccc} & & A \\ A & & B \quad C \\ B & & C \quad D \\ & & D \end{array}$$

~~ABA or BAA~~

then Try BAA

$$BAA\;\begin{array}{ccc} & A & \\ A & B & C \\ B & C & D \\ & D & \end{array}$$

~~AAB AAB~~
~~ABA ABA~~
~~BAA BAA~~
~~BBA BBA~~
~~ABB ABB~~
~~BAB BAB~~

Try

$$\begin{array}{ccc|ccc|ccc} & & A & & & A & & & A \\ A & C & B & A & C & B & A & C & B \\ B & D & C & B & D & C & B & D & C \\ & & D & & & D & & & D \end{array}$$

Add AAB

$$AAB,\begin{array}{ccc} & & A \\ A & C & B \\ B & D & C \\ & & D \end{array} \qquad \begin{array}{ccc} & & A \\ A & C & B \\ B & D & C \\ & & D \end{array}.AAB$$

ok.

and BBA. AABBBA BBA,AAB

$$BBA\left|\begin{array}{ccc} & & A \\ A & C & B \\ B & D & C \\ & & D \end{array}\right|BBA$$

Then for eighten

$$\begin{array}{ccc} & & A \\ A & C & B \\ B & D & C \\ & & D \end{array}$$

plus AAB
+ BBA

Suppose we add

$$\begin{array}{ccc} A & A & A \\ B & B & B \end{array} \left|\begin{array}{ccc} & & A \\ A & C & B \\ B & D & C \\ & & D \end{array}\right| \begin{array}{ccc} A & A & A \\ B & B & B \end{array}$$

no false one with the ...

Then suppose $\overset{x}{AAB} + \overset{s}{AAA}$
$\overset{y}{BBA} + \overset{t}{BBB}$

call The following

xs
xt
sx
xt
yt
ys
sy

∴ 12 possibilities

	x	y	s	t
x	✓	×	✓	×
y	×	✓	×	✓
s	×	×	×	×
t	×	×	×	×

Add AAB
BBA

CDC
DCD

A C A
B D B
C
D

Subtract CDC-DCD
DCD-CDC

AC A
BD B - CDC -8

~~—~~ CDC
ditto - DCD -8

Gly Al

Val, Leu, Ileu, Pro

Ser. Thre.

Asp. Glut.

Asp NH2. Glu NH2

Phenyl, Tyrosine.

~~Lysine - arginine~~

Histidine

Tryptophane.

Cysteine - Methionine. } Rare?

~~Lysine arginine~~.

? × 2 × 4

1st	2nd	3rd
Same or connected (these are big)	Type or Similar	

1st	2nd	3rd
polar or non polar	Shorter or longer.	Large

Try $\overset{x}{AAB}$ and $\overset{s}{BAA}$

$\overset{y}{BBA}$ $\overset{t}{ABB}$

A C A
B D B
C
D

	x	y	s	t
x	×	×	×	✓
y	×	×	✓	×
s	✓	×	×	×
t	×	✓	×	×

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SOME FEATURES OF THE AMINO-ACID COMPOSITION OF PROTEINS

By K. Bailey

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(*Presented to the Food Group Symposium on Amino-Acids and Protein Hydrolysates on September 29, 1949*)

ONE of the most disheartening features of the amino-acid analysis of proteins is that the results have little meaning. To a limited extent they are useful for assessing the nutritional value of a protein but they do not explain at all the true biological function; why one protein is an enzyme, another a hormone, another a toxin. This statement is true only for the consideration of the relative amounts of individual amino-acids in any one protein. It is less true when one considers groups of amino-acids which have common characteristics, e.g. the dicarboxylic acids, the bases, and the acids with lipophilic side chains. This qualification is so important that it needs to be enlarged upon.

Protein interactions

Proteins exercise their biological function by the ability to interact specifically with other molecules. The most familiar example of such interaction is the union of an enzyme and its substrate. There are, however, many other examples of specific interactions: the union of protein and prosthetic group, the combination of antigen and antibody, the interaction of "monomer" proteins to give fibres. In addition to specific interactions, all soluble proteins are capable of non-specific interaction with simple salts, zwitter ions or with other proteins. The earliest classification of proteins, based largely on solubility properties, made use of this type of interaction. An example is the insolubility of globulins in water and solubility in dilute salt solutions. Such interactions are amenable to quantitative treatment and are merely the expression of how the electrostatic forces which arise from the charged (positive and negative) groups are modified in the presence of other ions. To this extent, therefore, the amino-acid analysis of a protein, and in particular the numbers of base and free-acid groups, can be related to the solubility characteristics of a protein. But this by itself does not suffice to predict that a given protein is a globulin or an albumin; the manner in which the charged groups are distributed on the surface of the protein is of paramount importance.

There is no need to assume that the more specific interactions are either more or less complicated than the non-specific. They are concerned merely with a part of the protein surface and the forces operating may be of several types; the purely electrostatic, the partially ionic (H bonds) and the van der Waals' forces between the lipophilic parts of the molecules concerned. The problem here is really stereochemical; how amino-acid side chains are arranged so that all these forces can augment each other with respect to the interacting molecule. To the solution of this problem conventional amino-acid analysis contributes little or nothing.

Use and presentation of results

In view of this pessimistic evaluation, it is reasonable to enquire why proteins are analysed at all. The amino-acid balance sheet is important to the nutrition expert, though he is less interested in the composition of a pure protein than in the amino-acids of a complete article of diet. The real answer is that the analytical data will be useful in studies which aim at the determination of amino-acid sequence. Of this, Sanger's work[1] on insulin is an excellent example. Often the data are also useful in providing an independent check on the molecular weight of proteins as deduced from physico-chemical measurements. A decade ago it was considered that amino-acid analysis would provide a stoichiometric key; that amino-acids might be present in proportions which indicated a simple frequency of occurrence along the peptide chain. There is very little reliable evidence for such a belief, and it must be confessed that the laws governing the synthesis of proteins are entirely unknown.

Even if we set aside the real significance of the amino-acid contents of proteins, it is still difficult to assess the differences which exist when we compare the composition of a whole variety of proteins. I have made an attempt to remedy this situation by presenting the results of analysis in a different way. Only in the last few years have reliable methods for the monoamino-monocarboxylic acids (including the OH acids) been developed, and Tristram has recently collected the data for some 25 proteins.[2] The basis for his selection was that the analyses themselves should be both reliable and complete, and the proteins pure. Anyone interested in the amino-acid analysis of proteins must have been struck by the large variations in the amounts of some acids and by the relative constancy of that of others. The best way of illustrating this feature is to plot the results in the form of histograms.

Let us assume for the moment that we can make a purely random selection of proteins. Since the average residue weight shows little variation from one protein to another (except in certain special proteins), we can also assume that there are approximately 900 amino-acid residues/10^5 g. of protein. Histograms can be constructed showing the frequency of occurrence of individual amino-acids over fairly small units of grouping, say 5 to 10 residues in a total of 900. The same procedure can be used for whole groups of amino-acids, basic, acidic, lipophilic and so on. Here, it is more convenient to plot the amounts as a percentage of the total residues.

It must be said at once that the most difficult feature of this approach is the selection of data. There do exist groups of proteins the amino-acid pattern of which is similar. A very striking example of this is shown by certain seed globulins analysed by Smith and his co-workers[3] (Table I). Here we

Table I

Amino-acid analysis of seed globulins

	Results in g./100 g. protein				
	Edestin	Pumpkin	Squash	Cucumber	Tobacco
Arginine ..	16·7	16·2	16·2	15·8	16·1
Histidine ..	2·5	2·2	2·2	2·3	2·2
Lysine ..	2·35	2·75	3·0	2·95	1·6
Threonine ..	3·15	2·6	2·8	3·6	4·2
Leucine ..	7·4	8·0	8·0	9·1	10·5
*iso*Leucine ..	6·2	5·1	5·5	5·5	6·3
Valine	6·6	6·5	6·5	7·0	6·7
Tyrosine ..	4·35	4·35	4·35	4·6	4·1
Tryptophan ..	1·25	1·75	1·75	1·9	1·5
Phenylalanine..	5·45	7·2	6·8	6·5	5·7
Methionine ..	2·2	2·3	2·3	2·5	2·2
Cystine ..	1·3	1·1	1·1	1·1	1·1

have an identical amino-acid pattern not only for the globulins from related species, but also from two which are unrelated (tobacco and hemp). If all proteins could be divided into groups, one could select the data representative of each group and construct histograms from these prototypes. But there exist other groups the members of which are similar in certain respects and not in others, and we meet a problem which is essentially teleological—that the data cannot be selected until the significance of the amino-acid composition is known!

It is convenient to summarize the findings under three headings: the essential amino-acids (Fig. 1), the dispensable (Fig. 2) and those concerned with whole groups of amino-acids (Fig. 3).

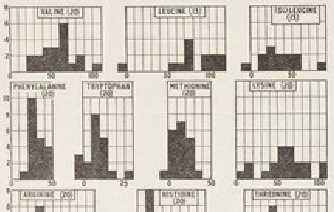

Fig. 1

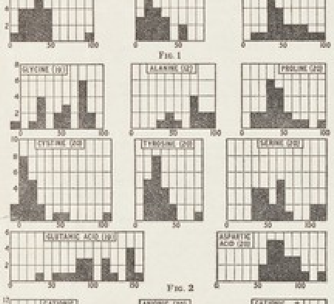

Fig. 2

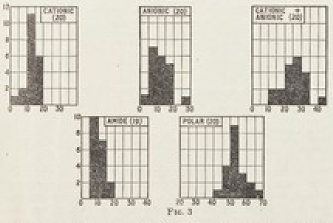

Fig. 3

Figs. 1, 2 and 3. The ordinates represent number of proteins (total considered given in parentheses). Abscissae: units of grouping as residues/10⁵ g protein (Figs. 1 and 2) and as percentage of the total residues (Fig. 3). Amino-acids entirely absent are shown to the left of the origin.

There exists also another problem of selection which concerns the complexity of the molecules investigated. The laws governing the synthesis of the simpler proteins such as the protamines, which may be thought of as extended polypeptides, may differ from those which govern the synthesis of the highly organized structure which is to be found in the denaturable proteins. The present selection of proteins is characterized as follows: (1) it is random in that the proteins, for various unconnected reasons, happen to have been analysed completely, and happen also to be pure or very nearly so; (2) it consists only of soluble proteins in which some degree of structural complexity is known. The complete list of proteins is set out in Table II; 17 are from

Table II

List of proteins for which complete (or almost complete) amino-acid analyses exist

(Only the soluble complex proteins are considered)

Aldolase	α-Globulin (human)
Caseinogen	β-Globulin (human)
Edestin	γ-Globulin (human)
Insulin	Tropomyosin
Ovalbumin	Myosin
Fibrinogen	Triosephosphate dehydrogenase
Haemoglobin (horse)	Pepsin
Myoglobin (horse)	Chymotrypsin
Lactoglobulin	Ribonuclease
Serum albumin	Pituitary lactogenic hormone

Tristram's compilation, two are my own (myosin and tropomyosin),[4] and the data for pituitary lactogenic hormone[5] are also included.

Essential amino-acids

Valine. Wide range of values, but no protein without.

Leucine. Usually present in large amounts in a range varying from 50 to 120 residues/10^5 g.

iso*Leucine.* Except in one case (pepsin), present in smaller amounts than leucine (between 0 and 60 residues).

Phenylalanine. Always present in rather constant amount, within a range of 25—50 residues.

Tryptophan. The amounts are usually small (0—15 residues) and some proteins are without.

Methionine. As for tryptophan, but a wider range of values (0—30 residues).

The basic amino-acids. Whilst the distribution of lysine is entirely erratic between 0—110 residues, the necessary amino-acid arginine has an even distribution between 10 and 50 residues. The amounts of histidine are generally smaller than those of arginine except in proteins of the histone type.

Threonine. Variable amounts, rarely less than 30 residues.

Dispensable amino-acids

Glycine and alanine. Distribution entirely erratic.

Proline. Invariably present over a wide range of values.

Cystine. Most proteins have very little (0—20 residues), but occasionally the amount is very large (keratin and insulin).

Tyrosine. For the majority of proteins, between 10—50 residues and always present in soluble proteins. Occasionally found in large amount (pepsin, insulin).

Serine. Very variable in amount, never less than 30 residues; there is generally more serine than threonine.

Aspartic and glutamic acids. Very variable amounts of both acids (30—160 residues for glutamic, 50—110 for aspartic); usually less aspartic than glutamic. (These values include the acids which occur as amides; the distribution of non-amidized glutamic and aspartic acids cannot be evaluated.)

Groups of amino-acids

Anionic and cationic groups. The numbers of cationic groups fall within a narrower range of values than the anionic. The interesting fact is that when the two are summated, a statistically normal distribution results, with the median value at about 25% of the total number of residues and a range from 13%—45%.

Amide. Whilst large variations are found in the free anionic groups, the amidized COOH groups fall within a fairly narrow range. This seems to indicate that the incorporation of asparagine and glutamine into the protein molecule is unconnected with that of the corresponding free acids. In other words, the anionic charge is effected by varying the amount of free acid and not by blocking some portion of a rather constant amount of the dicarboxylic acids.

Total polar groups. These represent the sum of the free acid groups, bases, amides, hydroxy acids, cystine and tryptophan (see Tristram[2]). They appear to have a statistically normal distribution with a median value somewhat greater than 50% and a range 44%—66%.

General conclusions

Any general conclusions which may be derived from these diagrams are circumscribed by the uncertainties in the selection of data. There are strong suggestions, however, that the complex type of soluble protein considered here can exist by virtue of certain conditions, viz., that there must be an upper and lower limit both to the total charge and to the number of polar groups. That a lower limit exists is understandable, since these groups are largely responsible for the forces which give the molecule a configurational stability. The upper limit may indicate that for the purpose of specific interaction, the lipophilic side-chains are no less important than the hydrophilic. Concerning individual amino-acids, the data merely set us further problems to which no answer can yet be given: We are led to enquire why amino-acids like valine, phenylalanine and tyrosine are always present, the last two in rather constant amounts, whilst others, such as glycine, tryptophan, methionine, may be dispensed with; why proteins contain very large amounts of an amino-acid like leucine and rather small amounts of cysteine and tryptophan. By comparing the analysis of any one protein with the type of distribution found in the histogram diagrams, one might be led to discover groups of functional significance. Thus, the activity of insulin is intimately connected with the intactness of its disulphide bonds, and the cystine value for insulin is far removed on the histogram from the grouping in the case of other proteins.

Table III

Comparison of analyses of albumins and globulins

	Results as % of total groups Cationic (C)	Anionic (A)	Total (C + A)	Polar
True albumins				
Ovalbumin	11·5	13·9	25·4	47·3
Serum albumin ..	16·9	15·8	32·7	53·0
Albumin-like				
Myoglobin	14·4	19·8	34·2	50·0
Ribonuclease	15·0	5·7	20·7	66·0
Triosephosphate D. ..	14·0	6·4	20·4	47·4
Globulins				
Fibrinogen	14·9	12·3	27·2	58·0
Myosin	16·1	18·0	34·1	57·7
Tropomyosin ..	18·4	26·6	45·0	62·8
Lactoglobulin ..	12·3	18·5	30·9	54·2
γ-Globulin	11·1	7·5	18·6	54·2

Finally, the solubility properties of albumin and globulins suggest that the greater interaction of the latter with salts might be due to their higher valence, or to a greater asymmetry of charge distribution. Independent evidence from dielectric dispersion curves suggests the latter. The analytical data (Table 3) likewise suggest that the total charge in the case of albumins is not necessarily lower than that of globulins. Unfortunately, the data are incomplete, since many more globulins have been analysed than albumins.

If the conclusions from this type of approach are hazardous, I feel that the plotting of data in this way does at least give a bird's-eye view of the range of amino-acid values in the proteins thus far analysed.

Acknowledgment

I would like to thank Dr. G. R. Tristram for his kindness in placing at my disposal the amino-acid data which he has collected.

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Barkers Data (~ 20 proteins)

Valine ~ 60 -

Leucine 90 -

Isoleucine 35 -

Phenyl. 30 -

Tryp. ~~2~~15 -

Met 20 -

Lysine 60 -

Arg 30 -

Hist 25 -

Threo 55 -

Gly. 50 -

Ala 75 -

Pro 45 -

Cys ~20 -

Tyr 30 -

Ser 60 -

Glu + gluN 100

Asp + AspN 80

30

Thus

Common. Leu

Ala

Val

Ser

· Lys

Glu?

Threo

· Gly

GluN?

~~Gly~~

Pro

Glu Asp? AspN

· Isol.

Phe

Arg

Tyr

· His

· Cys

~~Trp~~

· Met

· Tryp

x4.
x4

xxx

xx.
xx.

[illegible]

Neighbours

Val	11
Leu	9
Tyr	9
Gly	9
Glu	10
Ala	8
Ser	10
Phe	9
Cys	11
Pro	8
Lys	6
Arg	7
GluN	6
	113

Thus a Gamow code impossible

new nearest

neighbour analysis   Gamow diamond code

	Total	No. arch	dia series	with itself		under & group
— Val	10			✓	•	His, Lys, Arg, GluN, ~~Ly~~ Pro, Ala,
— Leu	10			✓	•	GluN, Asp, AspN
— Tyr	~~6~~10			-	•	Pro, AspN, Ser, Ala, Lys
— Gly	8			✓	•	His, Arg, Pro, Lys,
— Glu	9			-	•	Ileu, ~~Glu~~ GluN, Pro
Ala	6	3	-	✓		
.... Ser	7	5	✓	✓		Ileu
— Phe	8			-	•	AspN, Ser, TRY, Arg,
— Cys	9			-	•	Ala, Ser, Asp, GluN, His
Pro	7	4	-	-		
Lys	7	3	-	-		
Arg	6	3	-	-		
GluN	6	4	-	-		
	103					

ie cannot fall into two mutually exclusive classes

Thus new nearest neighbours cannot be put into Gamow's code.

~~BF LMPOV~~
LMP FUV

~~BCK AST~~
KST
BCR

Ser his Leu val Leu Cys Gly Ser His Leu Val Glu Leu Val Glu Ala
GluN his Leu Cys Val Cys Gly Glu Tyr Leu Val Cys Isol Val Glu GluN

Val Glu Ala Leu Ala Leu Tyr Leu Leu Val Cys Gly Tyr GluN Leu Glu
Ala Glu Ala Phe Ser Leu Tyr GluN Ser (Gly) Val Cys Ser Asp GluN Leu Ala

GluN Leu Glu AspN Try Gly Lys Pro Lys Pro Val Gly
Pro Leu Glu Phe, Val Gly Lys Lys Arg Pro Val Lys.

Near neutral

Phe AspN..
Val GluN .2. ←
AspN His
GluN Leu
His Cys
Leu Gly
Cys Ser .2 ←
Gly His
Ser Leu
His Val
Leu Glu 2 ←
Val Ala
Glu Leu
Ala Tyr
Leu Leu
Tyr Val
Leu Cys
Val Gly
Cys Glu
Gly Arg
Glu Gly
Arg Phe
Gly Phe
Phe Tyr
Phe Thr
Tyr Pro
Thr Lys
Pro Ala

Gly Val
Isol-Glu
~~Val~~
Glu Cys
GluN Cys
Cys Ala
Ala Val
Ser Cys
Val Ser
Cys Leu
Ser Tyr
Leu GluN
Tyr Leu
GluN Glu
Leu AspN
Glu Tyr
AspN Cys
Tyr AspN

Ser Ser
Tyr Ser
Ser Glu
Ser His
Glu Phe -2 ←
His Arg
Phe Try
Arg Gly
Try Lys
Gly Pro
Lys Val
Pro Gly
Val Lys
Gly Lys
Lys Arg 2 ←
Arg Pro
Arg Val
Pro Lys
Val Val
Lys Tyr
Val Pro
Tyr Ala
Arg Leu
GluN Ala
Ala Ala
Glu Phe
Ala Pro.
Phe Leu
Pro Glu
Leu Phe.

5 pairs only.

His Glu

His Leu ✓
Cys Gly ✓
Leu Val ✓
Val Glu ✓
Glu Ala ✓
Leu Tyr ✓
Val Cys ✓
GluN Leu ✓
Leu Glu ✓
Gly Lys ✓
Pro Val ✓
11

Phe Phe
Cys Cys
Lys Lys
Arg Arg

Gly
Ala Val
Ser

Leu Glu Leu Leu Cys

Cys Ser Cys
(94)
Gly Pro Gly
Phe Leu Phe

Arg Val Val Pro
– Ser Ser Glu
GluN Ala Ala Pro

The Six Codes

Properties:

All six can have (a) any nearest neighbours

(b) any near nearest neighbours

Doubles and Triples (all doubles possible)

Code I : 4 triples only : which repeat the same.

This applies to all six.

The form XYX

Code I : only 4 possibilities for Y

all 16 possibilities for X : in 4 different ways

Code II 8 possibilities for Y

all 16 possibilities for X, in 4 different ways.

Code III 12 possibilities for Y

all possibilities for X, in 4 diff. ways.

Code IV ditto

Code V ditto.

Code VI ditto.

The forms YXX or XXY always four choices for Y for any one case.

check against the insulin sequence

Ala Gly Val

Cys Cys Thr Ser Ileu Cys

Ala Ser Val

Try code VI (G his idea)

Can we see. - Cys Cys Ala <u>Gly</u> Val Cys - ?

and Cys Cys Ala <u>Ser</u> Val Cys-

Cotton. . . . .

seems impossible to do on this code.

ABBCBDCA

Impossible on any of these codes.

AAA	1.	1000	BAA	16	0	CAA	11	0	DAA	6	0
AAB	2	0100	BAB	13	10	CAB	12	10	DAB	7	10
AAC	3	0010	BAC	14	1 · 0	CAC	9	1 · 0	DAC	8	1 · 0
AAD	4	0001	BAD	15	1 · · 0	CAD	10	1 · · 0	DAD	5	1 · · 0
ABA	5	1	BBA	4	1	CBA	15	1	DBA	10	1
ABB	6	1	BBB	1	1	CBB	16	1	DBB	11	1
ABC	7	1	BBC	2	1	CBC	13	1	DBC	12	1
ABD	8	1	BBD	3	1	CBD	14	1	DBD	9	1
ACA	9	1	BCA	8	1	CCA	3	1	DCA	14	1
ACB	10	1	BCB	5	1	CCB	4	1	DCB	15	1
ACC	11	1	BCC	6	1	CCC	1.	1	DCC	16	1
ACD	12	1	BCD	7	1	CCD	2	1	DCD	13	1
ADA	13	1	BDA	12	1	CDA	7	1	DDA	2	1
ADB	14	1	BDB	9	1	CDB	8	1	DDB	3	1
ADC	15	1	BDC	10	1	CDC	5	1	DDC	4	1
ADD	16	1	BDD	11	1	CDD	6	1	DDD	1.	1

"16" scheme

neighbours. before

		after
	1	1, 2, 3, 4, 1234 1234 1234 ! ! !
	10	9, 10, 11, 12, 9, 10, 11, 12 . . . .

unless

AAA

avoid AAA

or AAA

0

1

AAA	AAB
BBB	ABA
CCC	ACA
DDD	ADA

Code I

9
ACA
BCB
CCC
DCD

10
ACB
BCC
CCD
DCA

11
ACC
BCD
CCA
DCB

12
ACD
BCA
CCB
DCC

13
ADA
BDB
CDC
DDD

14
ADB
BDC
CDD
DDA

15
ADC
BDD
CDA
DDB

16
ADD
BDA
CDB
DDC

1
AAA
BAB
CAC
DAD

~~AAB~~
ABB

2
AAB
BAC
CAD
DAA

3
AAC
BAD
CAA
DAB

4
AAD
BAA
CAB
DAC

5
~~ABA~~
ABA
BBB
CBC
DBD

6
ABB
BBC
CBD
DBA

7
ABC
BBD
CBA
DBB

8
ABD
BBA
CBB
DBC

no restriction on (a) nearest neighbours !!!
(b) next nearest neighbours.
for a set of sixteen. Thus more promising.

CAAC

2 6
DAABBC
2 6

Then a family of codes (six in all)

call them

I	II	III	IV	V		VI	
A	A	A	A	A	~~A~~	A	~~A~~
B	D	B	C	C	~~B~~	D	~~B~~
C	C	D	B	D	~~D~~	B	~~C~~
D.	B	C	D	B	~~C~~	C	~~D~~

6 ways

A	D	A	B	C
B	C	D	A	B
C	B	C	D	A
D	,A	,B	,C	,D

A	D	C	B	A
B	C	B	A	D
C	B	A	D	C
D	,A	,D	,C	,B

the same.

A
D B
C

A
B D
C

A
C B
D

A
C

Another possibility.

~~AAA~~	A
~~BBB~~	B
~~CCC~~	C
~~DDD~~	D

AAA	AAB	AAC	AAD
ABA	ABB	ABC	ABD
ACA	ACB	ACC	ACD
ADA	ADB	ADC	ADD

BAA	BAB	BABC	BAD
BBA	BBB	BBBC	BBD
BCA	BCB	BCBC	BCD
BDA	BDB	BDBC	BDD

CAA	CAB	CABC	CAD
CBA	CBB	CBBC	CBD
CCA	CCB	CCBC	CCD
CDA	CDB	CDBC	CDD

DAA	DAB	DABC	DAD
DBA	DBB	DBBC	DBD
DCA	DCB	DCBC	DCD
DDA	DDB	DDBC	DDD

This is ~~restriction~~

no restriction on nearest neighbours
but restriction on next nearest. (Same, or each side, only)

Code II

1	2	3	4
AAA	AAB	AAC	AAD
BAD	BAA	BAB	BAC
CAC	CAD	CAA	CAB
DAB	DAC	DAD	DAA

5	6	7	8
ABA	ABB	ABC	ABD
BBD	BBA	BBB	BBC
CBC	CBD	CBA	CBB
DBB	DBC	DBD	DBA

9	10	11	12
ACA	ACB	ACC	ACD
BCD	BCA	BCB	BCC
CCC	CCD	CCA	CCB
DCB	DCC	DCD	DCA

13	14	15	16
ADA	ADB	ADC	ADD
BDD	BDA	BDB	BDC
CDC	CDD	CDA	CDB
DDB	DDC	DDD	DDA

Code III

1	2	3	4
AAA	AAB	AAC	AAD
BAB	~~BAC~~	BAD	BAA
~~CAD~~	CAA	CAB	CAC
DAC	DAD	DAA	~~DAB~~

5	6	7	8
ABA	ABB	ABC	~~ABD~~
BBB	BBC	BBD	BBA
CBD	~~CBA~~	CBB	CBC
~~DBC~~	DBD	DBA	DBB

9	10	11	12
ACA	~~ACB~~	ACC ✓	ACD
BCB	BCC	~~BCD~~	BCA
CCD	~~CCA~~	CCB	CCC
DCC	DCD	~~DCA~~	DCB

13	14	15	16
ADA	ADB	~~ADC~~	ADD
BDB	BDC	BDD	~~BDA~~
CDD	CDA	~~CDB~~	CDC
DDC	DDD	DDA	DDB

Code V

1	2	3	4
AAA	AAB	AAC	AAD
BAC	BAD	BAA	BAB
CAD	CAA	CAB	CAC
DAB	DAC	DAD	DAA

5	6	7	8
ABA	ABB	ABC	ABD
BBC	BBD	BBA	BBB
CBD	CBA	CBB	CBC
DBB	DBC	DBD	DBA

9	10	11	12
ACA	ACB	ACC	ACD
BCC	BCD	BCA	BCB
CCD	CCA	CCB	CCC
DCB	DCC	DCD	DCA

13	14	15	16
ADA	ADB	ADC	ADD
BDC	BDD	BDA	BDB
CDD	CDA	CDB	CDC
DDB	DDC	DDD	DDA

Code VI

1	2	3	4
AAA	AAB	AAC	AAD
BAD	BAA	BAB	BAC
CAB	CAC	CAD	CAA
DAC	DAD	DAA	DAB

5	6	7	8
ABA	ABB	ABC	ABD
BBD	BBA	BBB	BBC
CBB	CBC	CBD	CBA
DBC	DBD	DBA	DBB

9	10	11	12
ACA	ACB	ACC	ACD
BCD	BCA	BCB	BCC
CCB	CCC	CCD	CCA
DCC	DCD	DCA	DCB

13	14	15	16
ADA	ADB	ADC	ADD
BDD	BDA	BDB	BDC
CDB	CDC	CDD	CDA
DDC	DDD	DDA	DDB

check on pairs

doubles ~~triples~~ triples.

1.1. A.. AAAA .. A

2.2 DAAB .. ~~B~~

3.3. .. CAAC ...

4.4. .. BAAD ..

5.5. B.. BBBB .. B

66 .. ABBC ..

7.7. .. DBBD ..

8.8. .. CBBA ..

9.9. C.. CCCC .. C

10.10 .. BCCD ..

11.11 .. ACCA ..

12.12 .. DCCB ..

13.13 D.. DDDD .. D

14.14 .. CDDA ..

15.15 .. BDDB ..

16.16. .. ADDC ..

Thus only four triples possible; and there are ~~also~~ also the possible quadruples

code I

Thus double pairs, in sequence, are possible.

check on XYX forms.

Four ways for each one.

eg.

1 Y 1	2 Y 2	14 Y 14
AAAAA 1 1 1	AABAC 2 5 2	ADBDC 14 5 14
BABAB 1 5 1	BACAD 2 9 2	~~BCD~~ BDCDD 14 9 14
CACAC 1 9 1	CADAA 2 13 2	CDDDA 14 13 14
DADAD 1 13 1	DAAAB 2 1 2	DDADB 14 1 14

Thus only four possibilities for the middle (i.e. the Y) of XYX sequences!

Leu Ala Leu lysozyme.

Ser Tyr Ser
Val Tyr Val
Ala Glu Ala
B chain.

Leu Tyr Leu Insulin B

Code II

doubles. triple

1.1. AAAA ✓

2.2 BAAB ~~ABBAA~~ no

3.3. CAAC no

4.4. DAAD no.

5.5. DBBD no

6.6. ABBA no.

7.7. BBBB ✓

etc

ABBB

Code II xYx

1 Y 1	2 Y 2	14 Y 14
AAAAA (1 1 1)	AABAA (2 3 2)	ADBDA (14 7 14)
BADAB (1 13 1)	BAAAB (2 1 2)	BDADB (14 3 14)
CACAC (1 9 1)	CADAC (2 13 2)	CDDDC (14 15 14)
DABAD (1 5 1)	DACAD (2 9 2)	DDCDD (14 11 14)

ie. a difference set.

The middle one will always be of the form EFE

Thus we need only look for distributions of these

Code II

AAA	1	BAB	3	CAC	1	DAD	3
ABA	5	BBB	7	CBC	5	DBD	7
ACA	9	BCB	11	CCC	9	DCD	11
ADA	13	BDB	15	CDC	13	DDD	15.

∴ 8 possibilities.

Code III

1	1	4	2
5	5	8	6
9	9	12	10
13	13	13	14

Code IV

1	4	2	1
5	8	6	5
9	12	10	9
13	16	14	13

Code V

1	4	4	3
5	8	8	7
9	12	12	11
13	16	16	15

Code VI

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

Can the families be ~~sent~~ made the same only by permutation?

Write down 1 for all six families.

I	II	III	IV	V	VI
A A A	A A A	A A A	A A A	A A A	A A A
B A B	B A D	B A B	B A C	B A C	B A D
C A C	C A C	C A D	C A B	C A D	C A B
D A D	D A B	D A C	D A D	D A B	D A C

↓

? B B B
A C B A
D B D
A B C

new group.

or

D D D
A D C
B D B new gr.
C D A

or

B B B
A B D new group.
C B C
D B A

or

B B B
A B C
D B D new gr.
C B A

B B B $A \to B$
B $C \to C$
C B C
B

This looks at all different. !

Errors in Gamow's paper [Dan. Biol. Medd 22 no 3 (1954)]

List of amino acids

{ Cystine
{ Cysteic "acid"

hydroxyproline
Norvaline
hydroxyglutamic acid

{ Asparagine
{ glutamine

Canine

~~amines~~ important to distinguish between amides and corresponding acidic side-chains.

eg. in his argument.

Concept of "hereditary proteins"

Symmetry concepts states 4 =

1 ----
3 4
---- 4

also 4 :

1
4 3
4

and lack of direction

and.

4
3 4
1

and

4
4 3
1

Val - Lys - Val.

impossible for Val = a, b, d, f, m, h, j, u, e, o, g, n, l, t, k, w

~~BBA~~

~~AAAAA~~
C

~~BBBBB~~

~~DBBBB~~

BBDBD ✓

CACAA ✓

~~BABAB~~

~~ABABC~~
A

~~DABAB~~

BADAD ✓

DADAD ✓

CBCBA ✓

CBCBC ✓

ACACA ✓

ACACC ✓

BDBDB ✓

DDBDB ✓

~~BDDDD~~

~~CCCCA~~

~~CCCCC~~

~~DDDDD~~

BCBCB ✓

ADADA ✓

ADADC ✓

DCBCB ✓

~~BCDCD~~

~~DCDCD~~

~~CDCDA~~

possible. i s c r

∴ lys can be

c, r, i or s !!!

not c

r in ~~BCB~~ ~~ADA~~ ~~D~~

r in BCB
D

ADA
C

s in BAD
D

CBA
C

unambiguous to

one solution only

DCB
B

ADC
A

A → C
B → D

doubles

aa	BBAA D	ee	BDCA
		oo	CCCC A
bb	AAAA C		DDDD B
	BBBB D	rr	ADCB
dd	ABAB	nn	DDCC
	DABA	tt	DCDA B C
	BABC		CDCD
ff	CABD	ll	ACDB
ss	CBAD	kk.	CCDD
uu	AABB		

Plus possible double doubles.

AABBAA

AABBBB

DDDDCC B

ADCBAD

BDCABD

DDCCCC A

CCCCDD

DDCCDD

CCCABD

DCDABA B

BBAAAA D C

BBAABB D

AAAABB

AAACDB

BBBBAA D

BABCDA C

CBADCB

CABDCA

CABDDD

ACDBAA

ACDBBB

CCDDDD

CCDDCC

Lys ~~Lys~~ Arg Arg.

a a b b ✓

a a u u ✓

a a b b

u. BBAAAA

D C

~~a~~

a a w w

BBACDB

D

c e w

a a u u

or BBAABB

D

Lys Lys Arg Arg

b b u u

b b a a

b b u u

AAAABB

b b a a

BBBBAA

D C

~~Lys~~ L

~~d d f f~~

d d

~~ABABD~~

w x y z

q v

~~a b c d e f g h i j k l m n o p q r s t u v w x y z~~

self neighbour

ac	ee	no
bb	oo	i, m, h j, ø
dd	rr	
ff	nn	c, g w
ss	tt	
uu	ll	
	kk.	

h

l

Phe. Phe.

Cys. Cys.

Lys Lys

Arg Arg

t BCD
CDA
DCD
CDC

possible pairs = 64 × 4 = 256

but we can form 400

∴ some pairs must be forbidden

Types		no		
	AAA	4		α
	AAB	12	36	β_1
	~~ABC~~			β_2
	ABA	12		
	BAA	12		β_3
	ABC	24		γ

20
30
40

250

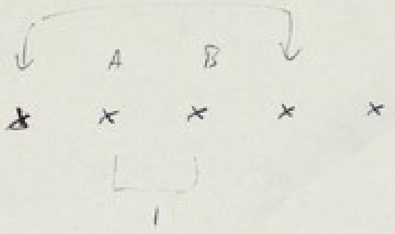
	~~allowed~~	forbidden		
allowed	$\alpha\beta_1$	$\alpha\beta_2$	$\alpha\beta_3$	$\alpha\gamma$
	$\beta_3\alpha$	$\beta_1\alpha$	$\beta_2\alpha$	$\gamma\alpha$
$\beta_1\beta_2$	$\beta_1\gamma$	$\boxed{\beta_1\alpha}$	$\beta_1\beta_2$	$\beta_1\beta_3$

4.3.2

~~RA~~

AB

Suppose ~~AB~~



97
64
161

Lys Lys Arg Arg

lev $\underline{A \to B}$

a $\quad B\boxed{A}A \quad D\boxed{A}A \quad B\boxed{B}C$

$\quad\;\; B\boxed{B}A \quad D\boxed{B}A \quad B\boxed{A}C$

m $\quad D\boxed{A}C$

$\quad\;\; D\boxed{B}C$

j $\quad C\boxed{A}D \quad$ ie. all in the middle ∴ <u>never change</u>.

$\quad\;\; C\boxed{B}B$

etc

lv $\underline{A \to C}$

a $\quad BB\boxed{A}$

$\quad\;\; BB\boxed{C}$

b $\quad AA\boxed{A} \quad$ all at the end !!

$\quad\;\; AA\boxed{C}$

etc

ETC Thus impossible.

h

Diamonds : rotational degeneracy.

2
1 2
1

2
1 2
2

2
1 2
3

2
1 2
4

3
1 2
1

3
1 2
2

3
1 2
3

3
1 2
4

4
1 2
1

4
1 2
2

4
1 2
3

4
1 2
4

by rotation, include all $2 \, {}^{n}_{m} \, 1$ type.

repeat
1
3 4 etc.
1

$\therefore$ 16+16 = 32 in all.

Now degenerate, so that 1 = 3.

we get 3 + 3 + 3 = 9 + 9 = 18

~~or if 1 2 = 3 only one top or bottom of diamond.~~

~~we get~~

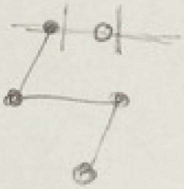
or allow only 1 position to degenerate

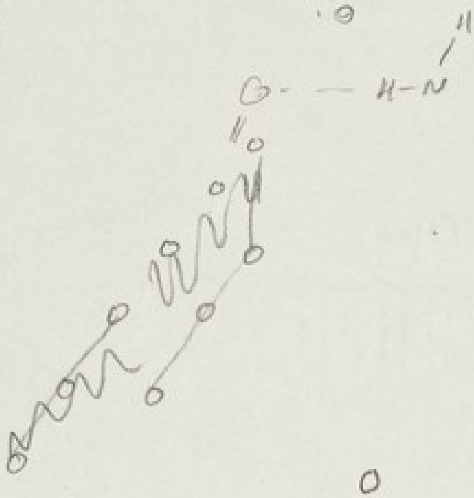
Then we save $\,_{1}{}^{3}{}_{2}\,$ 3 $\therefore$ 20

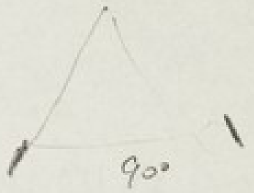
1=2

3=2

1



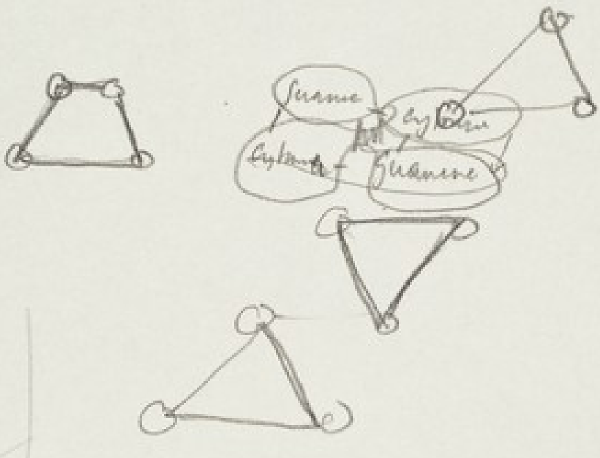


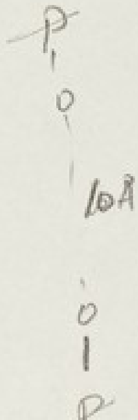


45

isoleucine
methionine
tryptophane

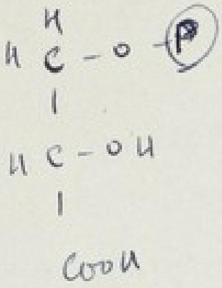
1 2

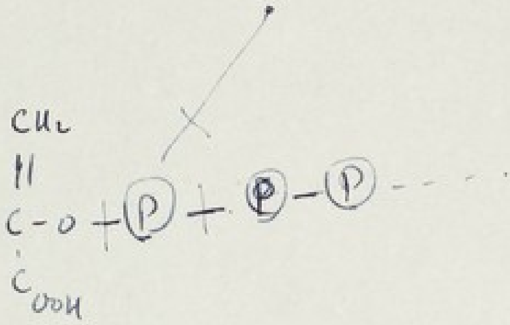




2.6
3
7.8

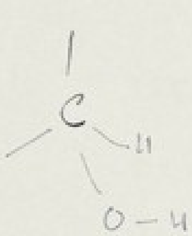
34 = 8|102
13
Å





Co I Ad. Nic am. Di N.

Co II .. + phos.



Gly - Lys - Pro - Val - Gly - Lys - Lys - Arg - Arg - Pro - Val - Lys - Val

Tyr - Pro -

Gly
Lys
Pro
Val
Arg.
(Tyr)

ABCDADACDA

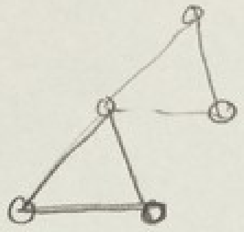
His Leu

Leu Val.

Cys Gly

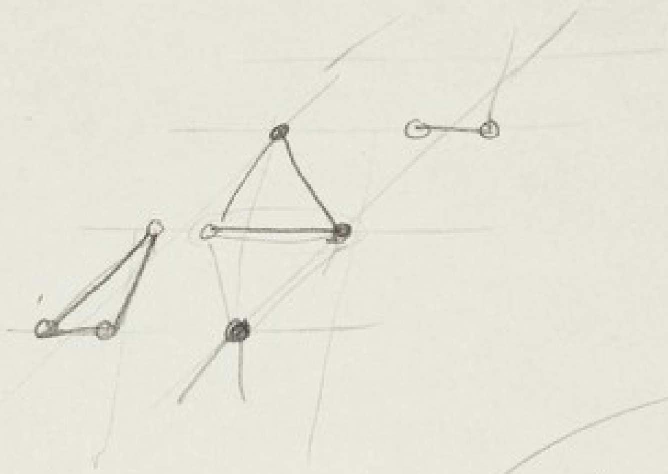
Pro Val

Gly Lys

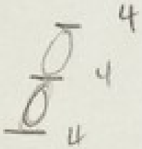


alternative position. i.e. bond on ring N of purine

rule
if the purine is bonded



Guanine - cytosine
- 3rd Hydrogen bond position



but pur pairs.

86

(90)

[illegible] rotated dependence

Convention.

etc.

sym. bonds

~~A~~

–, + 2

ABCD 4

ABCD 4

+, – 2

(64 pm.)

+ AA +	+ AB +	+ AB –	+ AA –
– AA –	+ BA +	– BA +	– ~~AA~~ +
+ BB +	– AB –	– AB +	+ BB –
– BB –	– BA –	+ BA –	– BB +
	+ AC +		
	+ CA +		
	etc.		

codes for	8 ~~8 fans~~	12	12	4 = 36
Total.	8	24	24	8 = 64

12

3 2 2 3 = 36

$\alpha\beta\gamma$ +,- +,- $\alpha\beta\gamma$ ~~with no~~

with restricted degeneracy.

write down the degenerate pairs

α + + α

α − − α

β + + β

⋮

γ

γ

$\left.\begin{matrix}\alpha - - \beta \\ \beta - - \alpha\end{matrix}\right\}$ $\left.\begin{matrix}\alpha + + \beta \\ \beta + + \alpha\end{matrix}\right\}$ $\left.\begin{matrix}\alpha + - \beta \\ \alpha - + \beta\end{matrix}\right\}$ etc

$\left.\begin{matrix}\alpha - - \gamma \\ \gamma - - \alpha\end{matrix}\right\}$ $\left.\begin{matrix}\alpha + + \gamma \\ \gamma + + \gamma\end{matrix}\right\}$ $\left.\begin{matrix}\alpha + - \gamma \\ \alpha - + \gamma\end{matrix}\right\}$

$\left.\begin{matrix}\beta - - \gamma \\ \gamma - - \beta\end{matrix}\right\}$

$\alpha\beta$

$\alpha\gamma$

$\beta\gamma$

3 × 3 degenerate pairs

∴ = 9 ∴ 27 possibilities

<u>Triplets</u> of type. +, -
ABCD
ABCD.

Total <u>32</u>

Allow variable dependence on the ~~or~~ [illegible]

Thus.	+ A A	- A A	+ A B	- A B
				- B A
	+ B B	- B B	+ A C	
			+ A D	- A C
	+ C C	- C C	+ B A	- C A
			+ B C	
	+ D D	- C D	+ D D	
			⋮	
	4	4	12	6 = 26
Total.	4	4	12	12 = 32

3 2 2 3

= 36

2 2 2 2

= 16

Degenerate Templates

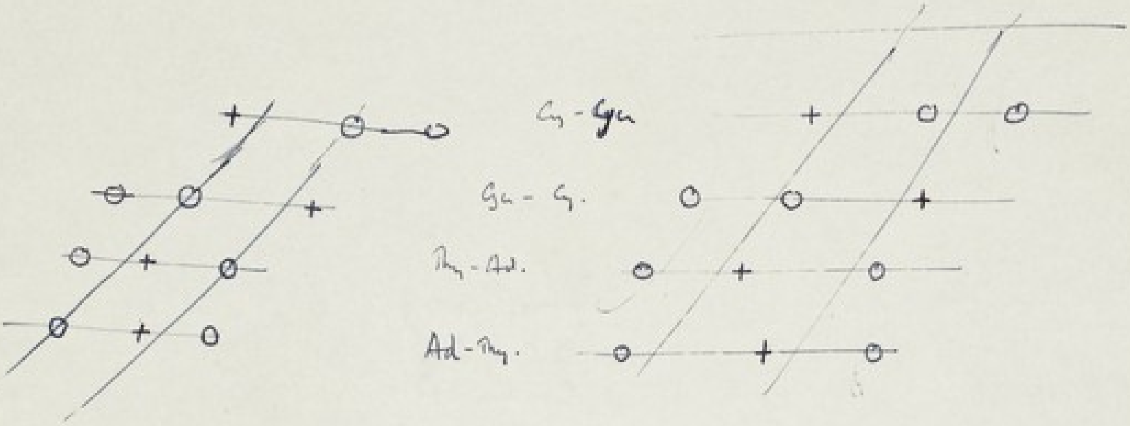
Let us abandon ~~rotational~~ degeneracy but retain 1=3 degeneracy.

1, 2, 4.

4. 1 2 2 1 3=1 4 4 3=1

1, 2, 4

Thus 36 possibilities.



allowed, ... GA.

~~AG~~

4^6 20^2

2^{12} 8^3 400

$\simeq 4000$

B D

A C

B A

D C

Cyt. — Gu
Gu — Cyt

G	C	A	A	T	T	C
C	G	A	T	T	A	A
A, U, G, (C)	A ~~...~~ C	A u G (C)	- - -	- -	-	
3+1	1+3	3+1	3+1	3+1	3+1	
	1	4	4	4	4	= 21

Suppose G had to be followed by C

~~... C followed by itself.~~

ie. ~~GA~~ ~~GT~~ ~~GG~~

~~Then 21 possibilities~~

Suppose G had to be followed by A

GA
GT
GG

G	C	·	A
A	T	G	A
		A	
4		4	

64
24
40

Triangle 16 cases

1
1 2

2
1 2

3
1 2

4
1 2

1
2 1

2
2 1

3
2 1

4
2 1

1
3 4

2
3 4

3
3 4

4
3 4

1
4 3

2
4 3

3
4 3

4
4 3

= 16.

~~if triangles rotational degenerate, we get.~~

if degenerate, so that 1 = 3, we get 12

Can we construct different codes giving identical sequences?

BAA / DAA BBA / BBC DBA / BBA

Consider

a BAA / BBA DAA / DBA BBC / BAC

e BCA / BDA BCA / BCC BCA / DCA

BDA / BDC BBA / DDA DCA / DDA BDC / BCC

b AAA / AAC BBB / DBB

c ACA / ACC BDB / DDB

i CAA / CAC BBD / DBB

o CCA / CCC BDD / DDD

d BAB / DAB ABA / ABC

r BCB / DCB ADA / ADC

h DAC / DBC

n ~~DCC / DDC~~ DCC / DDC

s BAD / DAD CBA / CBC

t BCD / DCD CDA / CDC

j CAD / CBB

k CCD / CDD

u AAB / ABB

w ACB / ADB

~~Ba~~ Diamond code : rotational degeneracy

+ 1=3 (once only) degeneracy.

Alphabet.

	1			1			1			3	
1		2	2		1	1		2	1		2
	1			1			3			1	

	1			2	
1		2	2		1
	2			1	

Permutation code

		before	after
		neighbours	
class 1	AAA, BBB, CCC, DDD	4 of class 2 } 4	same 4 of class 2
class 2	ABB ACC ADD BAA BCC BDD CAA CBB CDD DAA DBB DCC	1 of class 1 4 of class 2 2 of class 3 } total 7	
class 3	ABC BCD CDA DAB	6 of class 2 4 of class 3 } 10	

neighbours before and after must be the same in this case

Looks very restrictive.

$\boxed{\text{Thus impossible for straight}}$

ABB

BBB

BBA
C
D

ABC

ABA -
B -
C
D

BCA
B -
C -
D

ACA -
~~B~~
C -
D

ABC
D
~~A~~
~~B~~

BBA
B
C } 4

GluN has 6
Arg has 7
Lys has ~~6~~
Tyr has 9
Gly has 9
~~Ala has 9~~
Glu has 10
Pro has 8
Ala has 7

Phe	Glu
Leu	Leu
Ala	Lys
Tyr	Cys
Val	Ser
Arg.	Pro
Lys	Phe
Gum	7

Glu has 10
Phe has 9
Leu has 10
Ser has 10
Cys has 9

neighbours of Val

Asp NH$_2$
Cys
Glu
Gly
Lys
Tyr
Phe
Leu
Ileu
Ser
Pro

11 impossible

This clearly impossible

Skipping

a every other one

neighbours Val has 10 [illegible]

Leu has 10

Ser has 6

Ala has 7

Tyr has 10

Cys has 8

Glu has 9

Gly has 8

a too many with more than 7 neighbours

Cys His. Ser

Leu Glu

Glu Ala

Glu^{NH_2} Ser (Gly)

Gly Ser Leu

Asp^{NH_2} —

1 + 6

8

His
Leu
Glu
Glu^{NH_2}
Gly
Ser
Asp
Ala

<u>Fouriers</u>

Consideration of errors. Ratio of peak height to RMS background

RMS. background $= \dfrac{\left(\Sigma (\Delta F)^2\right)^{\frac{1}{2}}}{V}$ ΔF = errors.

Peak height $= \dfrac{\frac{1}{2} \sum \sqrt{\langle I \rangle}}{A \sqrt{N}}$ ($\frac{1}{2}$ for monoclinic?)

We shall have to assume some function to get small further. We take $\langle I \rangle = \langle I_0 \rangle \exp - BR^2$

and $(\Delta F) = R^{\frac{1}{2}} . E$ — whatever exp. variables (i.e. an error independent of I at any value of R, and increasing due to the Lorentz factor)

$\therefore (\Delta F)^2 = R . E^2$

<u>2D case</u>

$\therefore$ RMS Background $= \dfrac{\left(\sum RE^2\right)^{\frac{1}{2}}}{A}$

$m = \pi R_1^2 A$

$= \dfrac{\left(A \int^{2\pi R} RE^2 \, dR\right)^{\frac{1}{2}}}{A} = \dfrac{E}{\sqrt{A}} \left(\frac{1}{2} R_1^2\right)^{\frac{1}{2}}$

$E.R$

~~$k . 2\pi R^2 . A$~~

$k \pi R^2 A$

$\int k \, 2\pi R \, dR = k\pi R^2$

$= \dfrac{E}{\sqrt{A}} \left(\dfrac{2\pi R_1^3}{3}\right)^{\frac{1}{2}} = \sqrt{\dfrac{2\pi}{3A}} \; E R_1^{\frac{3}{2}}$

2D

Peak height $\langle I \rangle = \langle I_0 \rangle \exp - BR^2$

$$\therefore \quad = N f_0^2 \exp - BR^2$$

$$\frac{\sqrt{\langle I \rangle}}{\sqrt{N}} = f_0 \exp - \frac{B}{2} R^2$$

Vol volume $\frac{1}{2} A \sum f_0 \exp - \frac{B}{2} R^2$

$$= \frac{1}{2} A \int_0^{R_1} f_0 \exp\left(-\frac{B}{2} R^2\right) 2\pi R \, dR$$

$$= \cancel{\frac{1}{2} A f_0 \sqrt{\pi} \frac{Erf\left(\sqrt{\frac{B}{2}} R\right)}{2}}$$

Phase contrast $= \cancel{\dfrac{\frac{\sqrt{\pi}}{4} A f_0 \; Erf\left(\sqrt{\frac{B}{2}} R_1\right)}{\sqrt{\frac{2\pi}{3A}} \; E R_1^{\frac{3}{2}}}} = \text{contrast} \; \dfrac{Erf \sqrt{\frac{B}{2}} R_1}{R_1^{\frac{3}{2}}}$

~~Max when $\frac{d(\text{contrast})}{dR_1}$ = zero. looks like $R=0$!!?~~

$$= \frac{1}{2} A f_0 \frac{2\pi}{B} \left(1 - \exp\left(-\frac{B}{2} R_1^2\right)\right)$$

3

But, we have background due to the "cut-off" effect.

This is $\dfrac{\left(\sum_{R=R_1}^{R=\infty} I\right)^{\frac{1}{2}}}{A} = \dfrac{\left[A \int_{R_1}^{\infty} \langle I \rangle_0 \exp - BR^2 . \, 2\pi R \, dR \right]^{\frac{1}{2}}}{A}$

$$= \frac{\left(A \langle I_0 \rangle \frac{2\pi}{2B} \left[- \exp - BR^2 \right]_{R_1}^{\infty} \right)^{\frac{1}{2}}}{A}$$

$$= \frac{\left(A \langle I_0 \rangle \frac{\pi}{B} \exp - BR_1 \right)^{\frac{1}{2}}}{A}$$

Consider case of no errors.

Then contrast $= \dfrac{\sqrt{A} \; \frac{1}{2} f_0 \frac{2\pi}{B} \left(1 - \exp\left(-\frac{B}{2}R_1^2\right)\right)}{\sqrt{N} \, f_0 \sqrt{\frac{\pi}{B}} \exp - \frac{B}{2}R_1^2}$

Contrast $= \sqrt{\dfrac{A}{N}} \sqrt{\dfrac{\pi}{B}} \dfrac{\left(1 - \exp\left(-\frac{B}{2}R_1^2\right)\right)}{\exp - \frac{B}{2}R_1^2}$

for B small $\dfrac{1}{\sqrt{B}} \left(\dfrac{+ \frac{B}{2}R_1^2 + \cdots}{1 - \frac{B}{2}R_1^2} \right) = \dfrac{\frac{\sqrt{B} R_1^2}{2}}{1 - \frac{B}{2}R_1} \rightarrow \sqrt{B}$

$e^{x} = 1 + x +$

ie for B small, R_1 constant, B increases as $\sqrt{B}$ $\frac{B}{2}$

neglecting errors

Include errors

$\sqrt{R}$ type error.

$$\text{Total Background} = \frac{\left(AE^2\, 2\pi \frac{R_1^3}{3} + A\langle I_0\rangle \frac{\pi}{B} \exp - BR_1^2\right)^{\frac{1}{2}}}{A}$$

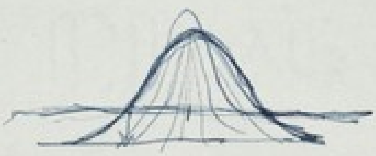
Then

$$\text{Contrast} = \frac{\sqrt{A}\, \frac{1}{2} f_0 \frac{2\pi}{B} \left(1 - \exp\left(-\frac{B}{2}R_1^2\right)\right)}{\left(E^2\, 2\pi \frac{R_1^3}{3} + N f_0^2 \frac{\pi}{B} \exp(-B_0 R_1^2)\right)^{\frac{1}{2}}}$$

At B "small" Sidelobes to make sharpening even more worthwhile!

$E \propto p\sqrt{N} f''$

$E^2 \propto p^2 N'' f^2$



Then $\dfrac{d(\text{contrast})^2}{dB} \times \left(\dfrac{N}{\pi A}\right) = \dfrac{-1}{B^2 \sqrt{B}} \left[\quad\right] + \dfrac{1}{B}\left[\dfrac{\frac{1}{2}R_1^2 \exp -\frac{B}{2}R_1^2}{\epsilon^2(1-\exp -BR_1^2) + \exp -BR_1^2}\right.$

How about change with R_1 ?

$\dfrac{1}{\sqrt{B}}\ \dfrac{1-\text{small}}{\epsilon^2+\text{small}}$

$\to \left(\dfrac{1}{\epsilon^2}\right)^{\frac{1}{2}} = \dfrac{1}{\epsilon}$

$\dfrac{d(\text{contrast})^2}{dR_1} \triangleq \quad \cancel{\text{exp}} \quad \epsilon^2$

~~(R_1 large)~~

$$\frac{d(\text{contrast})^2}{dB} \times \frac{N}{\pi A} = \frac{-1}{B^2}\left[\quad\right] + \frac{1}{B}\left[\frac{2\left(1-\exp -\frac{B}{2}R_1^2\right)\frac{R_1^2}{2}\exp -\frac{B}{2}R_1^2}{\epsilon^2(1-\exp -BR_1^2) + \exp -BR_1^2}\right.$$

$$+ \left.\frac{\left(1-\exp\left(-\frac{B}{2}R_1^2\right)\right)^2\left(\epsilon^2 R_1^2 \exp -BR_1^2 - R_1^2 \exp BR_1^2\right)}{\left(\epsilon^2(1-\exp -BR_1^2) + \exp -BR_1^2\right)^2}\right]$$

To get zero, take out factor

$$-\left[\epsilon^2(1-\exp -BR_1^2) + \exp -BR_1^2\right] - B\left[\overset{(1-\epsilon^2)}{\cancel{(\epsilon^2-1)}} R_1^2 \exp -BR_1^2\right]$$

$$+ B\left[\epsilon^2(1-\exp -BR_1^2) + \exp -BR_1^2\right]\left[R_1^2 \frac{\exp -\frac{B}{2}R_1^2}{\left(1-\exp -\frac{B}{2}R_1^2\right)}\right] = 0$$

Assume ϵ small, $\exp -BR_1^2$ small

$$+\epsilon^2 + B\,\cancel{(\epsilon^2)}\,R_1^2 \exp -BR_1^2 \simeq B\left[\epsilon^2 + \exp -BR_1^2\right] R_1^2 \exp -\frac{B}{2}R_1^2$$

$$\epsilon^2 \simeq BR_1^2 \exp -\frac{B}{2}R_1^2\left[\epsilon^2 + \exp -BR_1^2 - 1\right]$$

$$(\text{contrast})^2 \sim \frac{1}{B} \frac{\left(1-\exp\left(-\frac{B}{2}R_1^2\right)\right)^2}{\left(\exp - BR_1^2\right)}$$

$$\therefore \frac{d(\text{contrast})^2}{dB} = 0 \text{ for when } B\left(\exp - BR_1^2\right) \cancel{2\left(1-\exp\left(\frac{B}{2}R_1^2\right)\right)} \frac{R_1^2}{2} \exp - \frac{B}{2}R_1^2$$

$$= \left(1-\exp\left(-\frac{B}{2}R_1^2\right)\right)^2 \left(\exp - BR_1^2 + BR_1^2 \exp - BR_1^2\right)$$

$$BR_1^2 \exp - \frac{B}{2}R_1^2 = \left(1 - \exp - \frac{B}{2}R^2\right)\left(1 - BR_1^2\right)$$

$$BR_1^2 \cancel{\exp - \frac{B}{2}R_1^2} = 1 - \exp - \frac{B}{2}R_1^2 - BR_1^2 + BR_1^2 \cancel{\exp - \frac{B}{2}R_1^2}$$

$$\therefore 1 - \exp - \frac{B}{2}R_1^2 = BR_1^2 \quad \underline{\text{for minimum}}$$

$$1 - \exp - x = 2x$$

~~2x x 2x~~

$x < \frac{1}{2}$ $\quad 1 - \left(1 - x + \frac{x^2}{2} - \frac{x^3}{3} \dots\right) = 2x$

$$x - \frac{x^2}{2} + \frac{x^3}{3} \dots = 2x$$

$$-\frac{x^2}{2} + \frac{x^3}{3} \simeq x \qquad \therefore \cancel{\frac{x^2}{2} + x}$$

$x = 0$ is one soln!

$$-\frac{x}{2} + \frac{x^2}{3} = 1$$

$$2x^2 - 3x - 1 = 0$$

~~2x^2~~ $\qquad x = \frac{+3 \pm \sqrt{9+8}}{4}$

$$= \frac{+3 \pm \sqrt{17}}{4} \qquad \text{no solution!}$$

Try approximation on line.

$$(\text{contrast})^2 \simeq \alpha \; \frac{1}{B} \; \frac{\left(\frac{B}{2}R_1^2\right)^2}{\left(\ell^2 \frac{B}{2}R_1^2 + 1 - BR_1^2\right)}$$

$$\propto \; \frac{B^3}{1 - BR_1^2\left(1 - \frac{\ell^2}{2}\right)}$$

$\therefore$ zero when $\quad 3B^2\left(1 - BR_1^2\left(1-\frac{\ell^2}{2}\right)\right) = -B^3 R_1^2\left(1-\frac{\ell^2}{2}\right)$

$$1 - BR_1^2\left(1-\frac{\ell^2}{2}\right) + BR_1^2\left(1-\frac{\ell^2}{2}\right) = 0$$

impossible!

$\frac{u}{v}$

$= \frac{du}{v} - \frac{u\,dv}{v^2}$

$= \frac{v\,du - u\,dv}{v^2}$

Try another error curve

$$\text{i.e.}\quad (\Delta F) = \cancel{k\langle I_0\rangle}\ \frac{\epsilon}{k}\sqrt{\langle I_h\rangle}$$

$$= \cancel{\tfrac{1}{k}}\,\epsilon\,\langle I_0\rangle^{\frac{1}{2}}\exp -\frac{B}{2}R^2$$

$$= \epsilon\sqrt{N}\, f_0 \exp -\frac{B}{2}R^2$$

$$\therefore (\Delta F)^2 = \epsilon^2 N f_0^2 \exp -BR^2$$

$$\therefore\quad A\int_0^{R_1}(\Delta F)^2\, 2\pi R\,dR = A\epsilon^2 N f_0^2\int_0^{R_1} 2\pi R \exp -BR^2\, dR$$

$$= A\epsilon^2 N f_0^2 \cdot \frac{2\pi}{2B}\left(1-\exp(-BR_1^2)\right)$$

Then

$$\text{Contrast} = \frac{\sqrt{A}\ \cancel{\epsilon^{\frac12}}\ f_0\ \frac{2\pi}{B}\left(1-\exp\left(-\frac{B}{2}R_1^2\right)\right)}{\left(\epsilon^2 N f_0^2\,\frac{\pi}{B}\left(1-\exp -BR_1^2\right) + N f_0^2\,\frac{\pi}{B}\exp -BR_1^2\right)^{\frac{1}{2}}}$$

$$= \sqrt{\frac{A}{N}}\sqrt{\frac{\pi}{B}}\left[\frac{\left(1-\exp\left(-\frac{B}{2}R_1^2\right)\right)^2}{\epsilon^2\left(1-\exp -BR_1^2\right)+\exp -BR_1^2}\right]^{\frac{1}{2}}$$

variation with B ~~if B small:~~ ~~BR^2 small~~

$$\frac{\frac{1}{\sqrt{B}}\ \frac{B}{2}R_1^2}{\epsilon^2 BR_1^2 + \ldots\, BR_1^2 \ldots}$$

$$1+(\epsilon^2-1)$$

Sharpening

use hence $\exp + AR^2$ $\quad A < \frac{B}{2}$

for sharpening intensities

Then : peak goes $-\frac{(B-A)}{2}R_1^2$

diffn gets $-(B-A)R_1^2$

but error goes $(B-A)R_1^2$ also

$\therefore$ ok. to differential wrt. B.

---

approx value $\quad \epsilon^2 + \exp - BR_1^2 = 1$

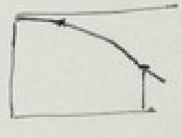
$\epsilon^2 \simeq 1 - \exp - BR_1^2$

$\epsilon^2 \simeq + BR_1^2$

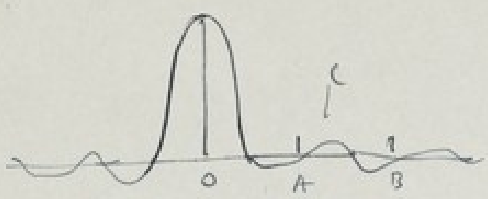
~~or [illegible]~~ $\quad R_1 \simeq \frac{\epsilon}{\sqrt{B}}$

ϵ is approx % error.

$\therefore$ if $\epsilon = \frac{1}{5}$ $\quad$ [illegible] $\quad R_1 \simeq \frac{1}{5\sqrt{B}} \quad \frac{1}{5}\left(\frac{1}{\sqrt{B}}\right)$



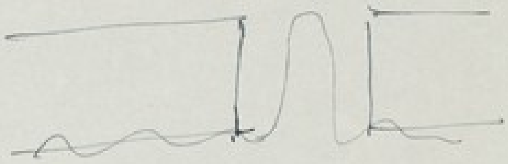
ie. appears to sharpen up a fair bit [illegible].

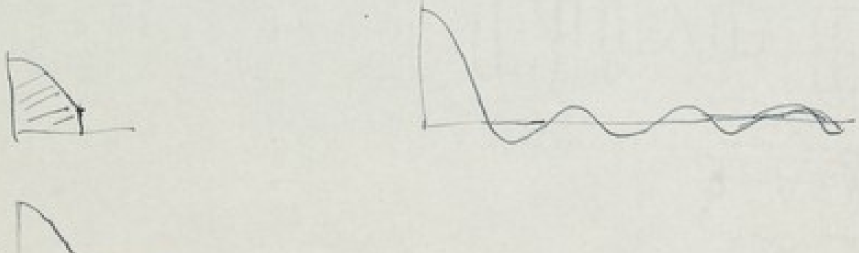


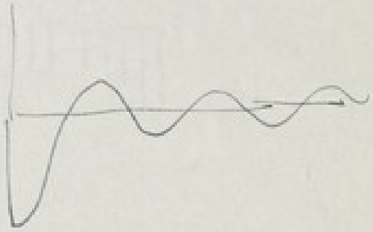
∴ $f(r_0)_a + 2f(r_A) + 2f(r_B)$ a maximum

compared to random sum of such around same line c

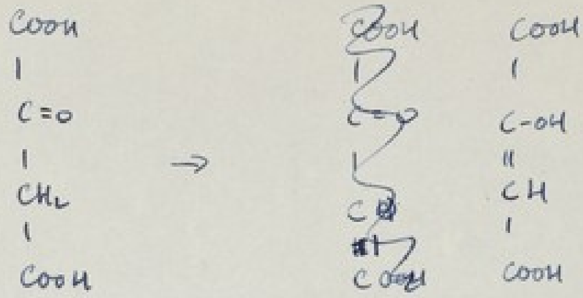
≥ no frequency higher than c cut off.



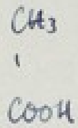




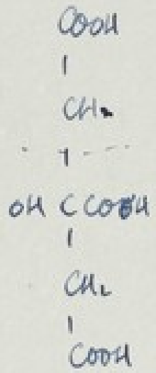
oxaloacetic acid.

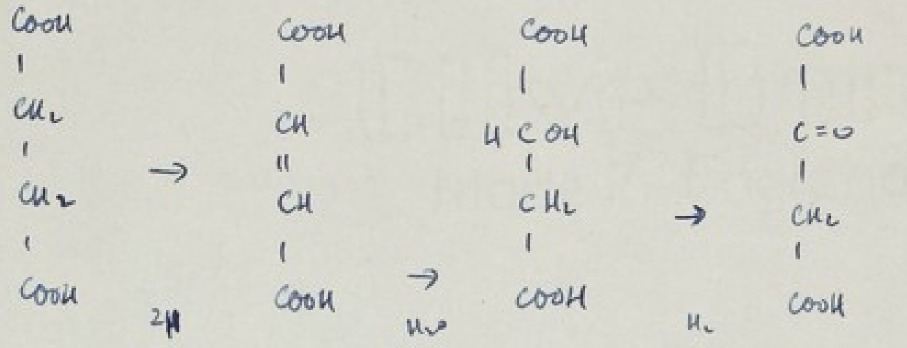


keto enol

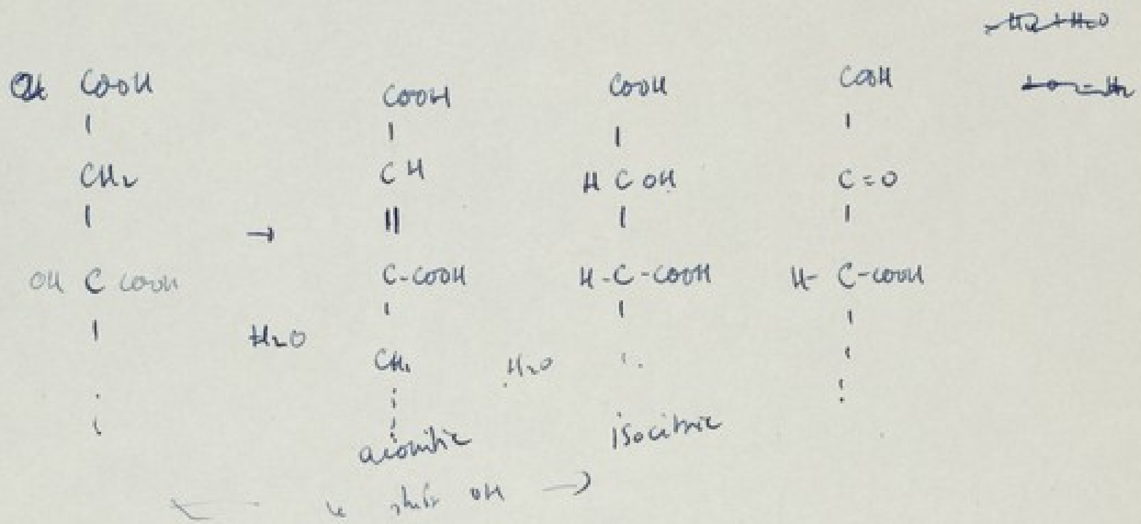
condensation with +  acetate

to give citric.



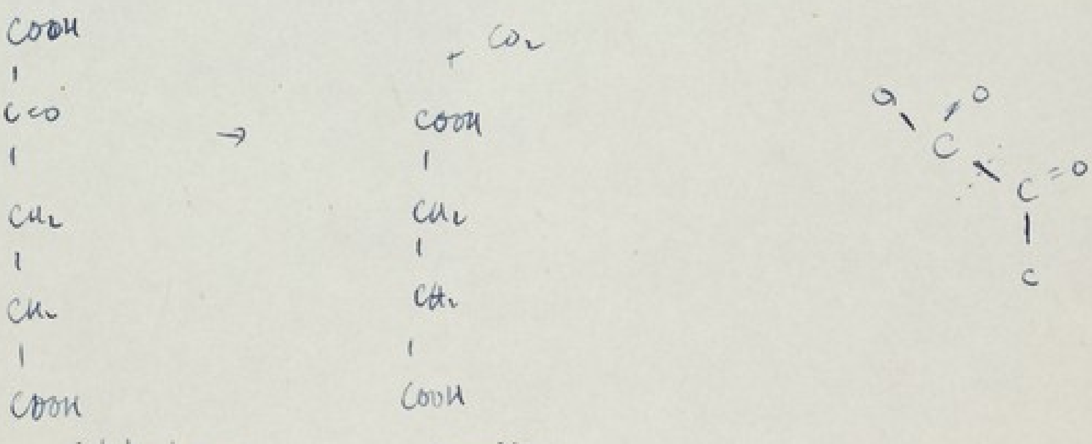


succinic. fumaric. malic oxaloacetic



aconitic isocitric

oxalosuccinic.



α keto glutaric. succinic

COOH
|
CH_2
|
CH_2
|
COOH

Succinic.

COOH
|
CHOH
|
CH_2
|
COOH

malic

COOH
|
CHOH
|
CHOH
|
COOH

tartaric

COOH
|
CH_2
|
C = O
|
COOH

oxaloacetic.

COOH
|
CH
||
CH
|
COOH

fumaric

COOH
|
CH_2
|
CH_2
|
CH_3

butyric.

COOH
|
CH_2
|
C=O
|
CH_3

β acetoacetic acid

COOH
|
HCOH
|
CH_2
|
COOH

β hydroxybutyric

COOH
|
CH_2
|
CH_3

propionic acid.

COOH
|
C=O
|
CH_3

pyruvic

COOH
|
COH
|
CH_3

lactic acid.

COOH
|
C–OH
||
CH_2

enol - pyruvic.

CH_2OH
|
CHOH
|
CH_2OH

glycerol.

CH_2OH
|
C=O
|
CH_2OH

dihy droxy acetone

CH_3
|
C=O
|
CH_3

acetone.

CH_3
|
CH_2
|
HC=O

propionaldehyde.

CH_2OH
|
CHOH
|
HC=O

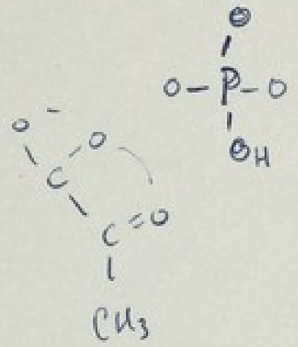
glyceraldehyde

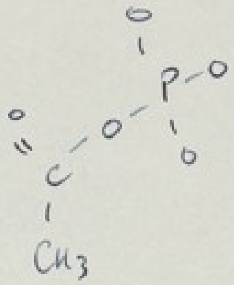
CH_3
|
CHOH
|
H C=O

COOH
|
CH_2
|
COOH

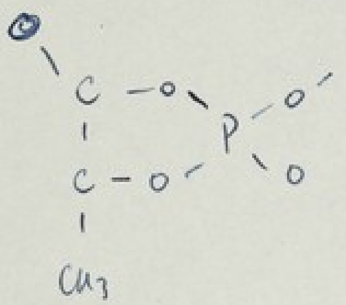
malonic

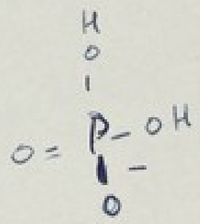
pyruvic. acetic

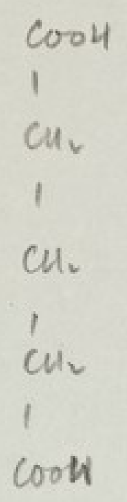




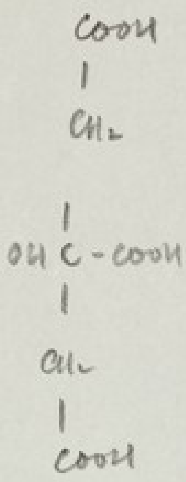
acetyl phosphate



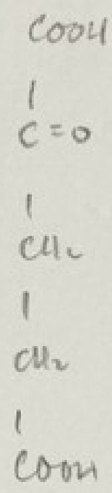




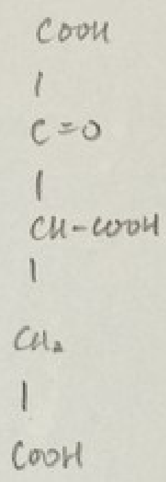
glutaric



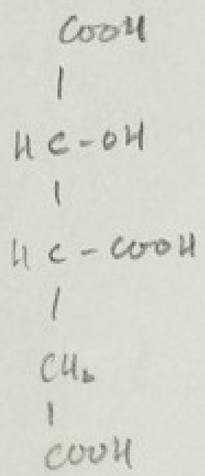
citric



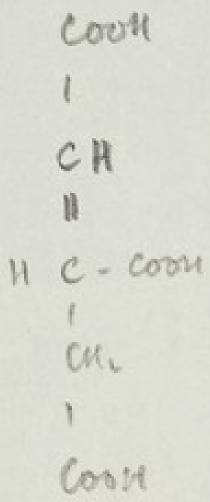
α-keto glutaric



oxalosuccinic



iso citric



aconitic

COOH	CH_3	H_2C-OH	COOH	COOH
|	|	|	|	|
COOH	H-C=O	H C=O	HC=O	H_2COH
oxalic	acetaldehyde	glycolic aldehyde	glyoxylic acid	glycollic acid

CH_2OH
|
CH_2OH
(ethyleneglycol.

glycolic acid $\overset{\overset{H}{O}}{\underset{H_2}{C}}-COOH$

α hydroxy propionic

$CH_3-CHOH-COOH$ lactic acid

β hydroxy propionic

CH_2OH-CH_2-COOH (hydracrylic acid).

malic acid

$\begin{array}{l} CHOH\ COOH \\ \vert \\ CH_2\ COOH \end{array}$

$\begin{array}{c} COOH \\ \vert \\ CHOH \\ \vert \\ CH_2 \\ \vert \\ COOH \end{array}$

alkanes

methane — methanol
ethane — ethanol — ethylene
propane — propanol — propylene
4 butane — butanol
pentane
etc.

∴ tertiary butyl

$$CH_3-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-OH$$

2-methyl-2, propanol

isopropyl $CH_3-\underset{\underset{\underset{H}{|}}{O}}{|}{CH}-CH_3$

or 2-propanol

CH_2OH
|
CH_2OH

glycol, ethylene glycol

1,2 ethanediol.

no $H_2C\begin{smallmatrix}-OH\\-OH\end{smallmatrix}$ H

CH_2OH
|
$CHOH$
|
CH_2OH

123 propanediol

glycerol.

"alkyl" = $-CH_3$ etc

$CH_2=CH-$ vinyl

CH_2OH
|
$CHOH$
|
$CHOH$
|
CH_2OH

erythritol

$\overset{|}{\underset{|}{C}}=O$ carbonyl

$\overset{|}{C}=O$ carboxylic
$|$
OH

formic

acetic

~~butyric~~

propionic

C_3H_7COOH butyric

valeric

caproic

—

caprylic

—

capric

—

lauric

—

~~my~~ myristic

palmitic

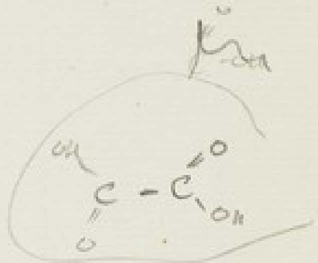
—

$C_{17}H_{35}COOH$ stearic

fatty acids

dicarbonylic

oxalic $\;COOH - COOH$



malonic

succinic $\;COOH - CH_2 - CH_2 - COOH$

glutaric

pimelic

oxalic
malonic
succinic
glutaric

acrylic $\;CH_2=CH-COOH$

crotonic — trans ~~C-COO~~

isocrotonic — cis

CH_3-C-H
$\quad\;\; \|$
$\; H-C-COOH$

maleic cis $\;H\,C-COOH \;=\; H\,C-COOH$

fumaric trans

General Schedule

elementary

Biochemistry

esp. intermediary metabolism.

Genetics

Sound elementary.

advanced

Virus work esp. phage.

Blood Groups

Antibody-reactions.

Genetics of microorganisms.

~~[illegible]~~. structure & localisation in cells.

Adaptive enzymes.

Special

Genetic effects on protein.

3

3 4

3 4 4 3

4

2 X 1 2 X 1

3 4 4 3

1 . 2 1 2

3 4

4 3

3 . 4

3 4

3 4

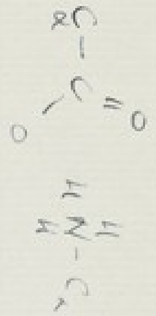
4 3

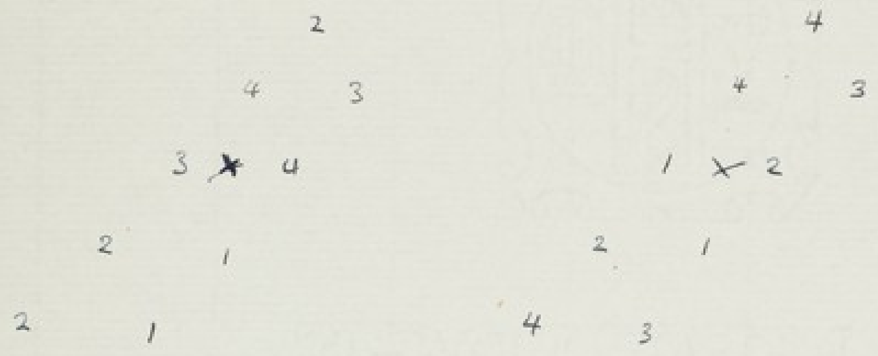
2 ? 1

2 1

4

3





3

I	T	O
Group I	Group II	Group III
Val	Asp.	Phe.
Leu	Glu	Cys ?
Gly	His	Ser ?
Ala	Arg.	Threo ?
Ileu	Lys.	Tyr. ?
		Pro ?
		Tryp.
		Meth.
		GluN

1. AspN (1). Tyr
2. Ser
1. Thre
2. GluN
1. Cys
1. Cys
1. Tyr.

Tyr Ser or Thre.

1	. .	Ser	. .	1
0	. .	Ser	. .	1
1	. .	Ser	. .	0
———		Ser	. .	0
———		Ser	. .	T
0	. .	Thr.	. .	1
2		6		2

AspN GluN.

———	. .	AspN	. .	1
1	. .	AspN	. .	1
1	. .	AspN		———
0	. .	GluN	. .	0
1	. .	GluN	. .	1
0(Ser)	. .	GluN	. .	1
———	.	GluN	. .	T
3		7		3

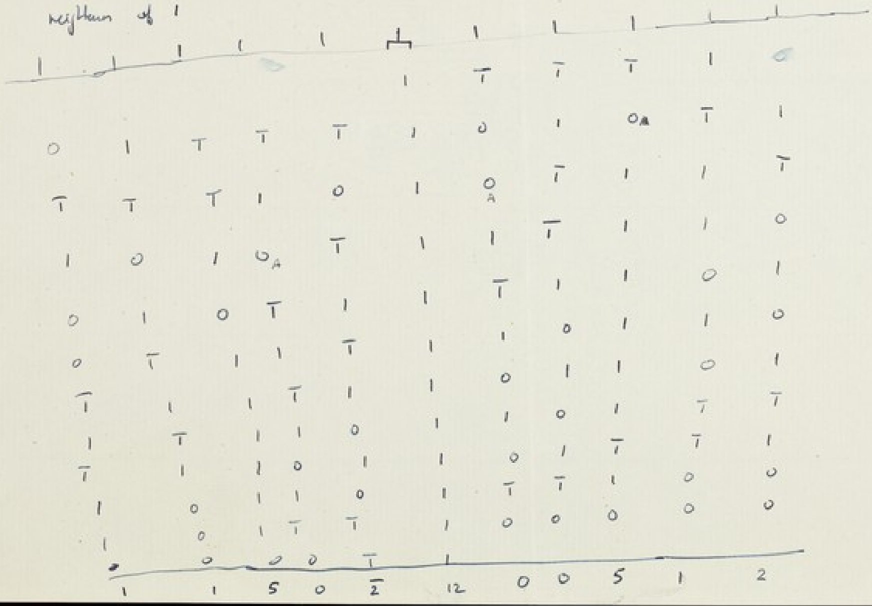
1 0 T

[illegible].

0 1 T T T 1 0 1 0 T 1 1 T 1 1 0 1 1 0 1 T T 1 0 0 0 0 0 T [illegible] 1 Insulin B.

$\frac{21}{7} = 3$!

neighbours of 1



[illegible] A

$1\,1\,1\,\bar{1}\,0\,0\,0\,1\,0\,1\,0\,0\,1\,0\,0\,1\,\bar{1}\,0\,0\,0\,0$

neighbours of 1.

$$
\begin{array}{ccccccccccc}
 & & & & & \perp & & & & & \\
 & & & & & 1 & 1 & 1 & \bar{1} & 0 & 0 \\
 & & & & 1 & 1 & 1 & \bar{1} & 0 & 0 & 0 \\
 & & & 1 & 1 & 1 & \bar{1} & 0 & 0 & 0 & 1 \\
1 & \bar{1} & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 \\
0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & \bar{1} & 0 \\
0 & 0 & 1 & 0 & 0 & 1 & \bar{1} & 0 & 0 & 0 & 0 \\
\hline
2 & \bar{1} & 2 & 2 & 2 & 7 & 0 & 1 & 1 & \bar{1} & 2
\end{array}
$$

β-corr.

$0\,0\,0\,0\,\bar{1}\,\bar{1}\,0\,\bar{1}\,0\,1\,\bar{1}\,0\,1\,1\,\bar{1}\,\bar{1}\,\bar{1}\,\bar{1}\,0\,1\,\bar{1}\,1\,0\,0\,1 \cdots \bar{1}\,0\,1\,1\,\bar{1}\,1\,0\,0\,1\,\bar{1}\,0$

neighbours of 1.

$$\bar{1}\quad \bar{1}\,\cdot\quad 0\quad \bar{1}\quad 0\quad \bar{\bar{1}}\quad \bar{1}\quad 0\quad 1\quad 1\quad \bar{1}$$

$$\bar{1}\quad 0\quad 1\quad \bar{1}\quad 0\quad 1\quad 1\quad \bar{1}\quad \bar{1}\quad \bar{1}\quad \bar{1}$$

$$0\quad 1\quad \bar{1}\quad 0\quad 1\quad 1\quad \bar{1}\quad \bar{1}\quad \bar{1}\quad \bar{1}\quad 0$$

$$\bar{1}\quad \bar{1}\quad \bar{1}\quad \bar{1}\quad 0\quad 1\quad \bar{1}\quad 1\quad 0\quad 0\quad 1$$

$$\bar{1}\quad \bar{1}\quad 0\quad 1\quad \bar{1}\quad 1\quad 0\quad 0\quad 1\quad \cdot\quad \cdot$$

$$1\quad \bar{1}\quad 1\quad 0\quad 0\quad 1\quad \cdot\quad \cdot\quad \cdot\quad \cdot\quad \cdot$$

$$\cdot\quad \cdot\quad \cdot\quad \bar{1}\quad 0\quad 1\quad 1\quad \bar{1}\quad 1\quad 0\quad 0$$

$$\cdot\quad \cdot\quad \bar{1}\quad 0\quad 1\quad 1\quad \bar{1}\quad 1\quad 0\quad 0\quad 1$$

$$\bar{1}\quad 0\quad 1\quad 1\quad \bar{1}\quad 1\quad 0\quad 0\quad 1\quad \bar{1}\quad 0$$

$$1\quad \bar{1}$$

$$\bar{1}\quad 0\quad 1\quad 0\quad 0\quad 1\quad \bar{1}\quad 0\quad \cdot\quad \cdot\quad \cdot$$

$$\bar{3}\quad \bar{4}\quad 1\quad \bar{2}\quad 0\quad 10\quad \bar{3}\quad \bar{1}\quad 2\quad \bar{2}\quad 0$$

$$2\quad \bar{1}\quad 2\quad 2\quad 2\quad 7\quad 0\quad 1\quad 1\quad \bar{1}\quad 2$$

$$1\quad 1\quad 5\quad 0\quad \bar{2}\quad 12\quad 0\quad 0\quad 5\quad 1\quad 2$$

Total

$$0\quad \bar{4}\quad 8\quad 0\quad 0\quad 29\quad \bar{3}\quad 0\quad 8\quad \bar{2}\quad 4$$

$$\uparrow \qquad\qquad\qquad\qquad\qquad\qquad\qquad \uparrow$$

Artificial sequence

1 1 1 0 0 1 $\bar{1}$ 0 1 $\bar{1}$ 0 $\bar{1}$ 0 1 0 1 0 1 0 1 0 1 0 1 0 1 $\bar{1}$ 1 1 1 0 $\bar{1}$

neighbours of 1.

.	.	.	.	.	1	1	1	0	0	1
				1	1	1	0	0	1	$\bar{1}$
			1	1	1	0	0	1	$\bar{1}$	0
1	1	1	0	0	1	$\bar{1}$	0	1	$\bar{1}$	0
0	0	1	$\bar{1}$	0	1	$\bar{1}$	0	$\bar{1}$	0	1
1	$\bar{1}$	0	$\bar{1}$	0	1	0	1	0	1	0
0	$\bar{1}$	0	1	0	1	0	1	0	1	0
0	1	0	1	0	1	0	1	0	1	0
0	1	0	1	0	1	0	1	0	1	$\bar{1}$
0	1	0	1	0	1	0	1	$\bar{1}$	1	1
0	1	0	1	0	1	$\bar{1}$	1	1	1	0
0	1	0	1	$\bar{1}$	1	1	1	0	$\bar{1}$	
1	0	1	$\bar{1}$	1	1	1	0	$\bar{1}$		
0	1	$\bar{1}$	1	1	1	0	$\bar{1}$			
3	5	2	5	3	14	1	7	0	4	1

$1\ \bar{1}\ \bar{1}\ 0\ 1\ 1\ \bar{1}\ \bar{1}\ 0\ 0\ \bar{1}\ 0\ 0\ 1\ \bar{1}\ 0\ \bar{1}\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ .\ .\ .\ \bar{1}\ 0\ 1\ 0\ 1\ \bar{1}\ \bar{1}\ \bar{1}\ 0\ 0\ 0$

					(4					
.	.	.	.	.	1	$\bar{1}$	$\bar{1}$	0	1	1
.	1	$\bar{1}$	$\bar{1}$	0	1	1	$\bar{1}$	$\bar{1}$	0	0
1	$\bar{1}$	$\bar{1}$	0	1	1	$\bar{1}$	$\bar{1}$	0	0	$\bar{1}$
0	0	$\bar{1}$	0	0	1	$\bar{1}$	0	$\bar{1}$	0	1
1	$\bar{1}$	0	$\bar{1}$	0	1	0	0	0	1	0
0	1	0	0	0	1	.	.	.	$\bar{1}$	0
.	.	.	$\bar{1}$	0	1	0	1	$\bar{1}$	$\bar{1}$	$\bar{1}$
.	$\bar{1}$	0	1	0	1	$\bar{1}$	$\bar{1}$	$\bar{1}$	0	0

2	$\bar{1}$	$\bar{3}$	$\bar{2}$	1	8	$\bar{3}$	$\bar{3}$	$\bar{4}$	0	0
1	0	2	1	1	7	0	$\bar{1}$	0	$\bar{3}$	0
3	5	2	5	3	14	1	7	0	4	1

6	4	1	4	5	29	$\bar{2}$	3	$\bar{4}$	1	1

1 0 1 0 0 1 $\bar{1}$ 1 1 $\bar{1}$ $\bar{1}$ 0 0 0 0 1 1 0 $\bar{1}$ 0 $\bar{1}$

.	.	.	.	.	1	0	1	0	0	1
			1	0	1	0	0	1	$\bar{1}$	1
1	0	1	0	0	1	$\bar{1}$	1	1	$\bar{1}$	$\bar{1}$
1	0	0	1	$\bar{1}$	1	1	$\bar{1}$	$\bar{1}$	0	0
0	0	1	$\bar{1}$	1	1	$\bar{1}$	$\bar{1}$	0	0	0
$\bar{1}$	0	0	0	0	1	1	0	$\bar{1}$	0	$\bar{1}$
0	0	0	0	1	1	0	$\bar{1}$	0	$\bar{1}$	.
1	0	2	1	$\cancel{3}$1	7	8	$\bar{1}$	0	$\bar{3}$	0

Transform of a spherical shell

volume element, dV,

we have contribution to ~~[illegible]~~ F is

$\exp 2\pi i(xX + yY + zZ)\, dV$

where $dV = \delta r . r\, d\phi . r \sin\phi\, d\theta$

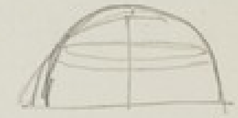
$z = r\cos\phi$

$y = r\sin\phi \sin\theta$

$x = r\sin\phi\cos\theta$

Since the answer will have spherical symmetry, we need only consider the case $X = Y = 0$.

dodle.



Or is $\iiint \exp 2\pi i\, (zZ)\, dV$

$= \iint \exp 2\pi i (r\cos\phi Z)\, r^2 \sin\phi\, d\theta\, d\phi\, \delta r$

$= r^2 . 2\pi\delta r \int_0^{\pi} \exp 2\pi i (r\cos\phi Z) \sin\phi\, d\phi$

$d\theta = dz\ \delta$

$dV = dz . \delta r\, r^2 d\theta$

$\iint \exp 2\pi i (zZ)\, dz\, \delta r\, r\, d\theta =$

$= 4\pi r^2 \delta r \int_0^r \cos(2\pi zZ)\, dz$

$2\pi r^2 \delta r \int \exp 2\pi i (zZ)\, dz$

$4\pi r^2 \delta r\ \dfrac{\sin(2\pi rZ)}{2\pi Z}$

$2\pi r \cos\theta \cdot 2 \cdot \frac{b}{\cos\theta}$

b

$\frac{b}{x} \cdot \cos\theta$

X - - - X

Ins A+B , β-Crt.

· Phe His
· Val Leu
· AspN Cys
· GluN Gly
· His Ser
· Leu His
· Cys Leu
· Gly Val
· Ser Glu
· His Ala
· Leu Leu
· Val Tyr
· Glu Leu
· Ala Val
· Leu Cys
· Tyr Gly
· Leu Glu
· Val Arg
· Cys Gly
· Gly Phe
· Glu Phe
· Arg Tyr
· Gly Thr
· Phe Pro
· Phe Lys
· Tyr Ala

· Gly GluN
· Isol Cys
· Val Cys
· Glu Ala
· GluN Ser
· Cys Val
· Cys Cys
· Ala Ser
· Ser Leu
· Val Tyr
· Cys GluN
· Ser Leu
· Leu Glu
· Tyr AspN
· GluN Tyr
· Leu Cys
· Glu AspN
~~AspN~~
~~Tyr~~
~~Cys~~

· Ser Glu
· Tyr His
· Ser Phe
· Met Arg
· Glu TRY
· His Gly
· Phe Lys
· Arg Pro
· TRY Val
· Gly Gly
· Lys Lys
· Pro Lys
· Val Arg
· Gly Arg
· Lys Pro
· Lys Val
· Arg Lys
· Arg Val
· Pro Tyr
· Val Pro
· Lys Ala

· Ala Asp

· Asp Glu
· GluN Ala
· Leu Phe
· Ala Pro
· Glu Leu
· Ala Glu
· Phe Phe
~~Pro~~

Repeats

Phe · Lys
Val · Tyr
Val · Arg
Leu · Glu
Leu Cys
Ser · Leu
Ser · Glu
Glu · Leu

8

5 pairs

X - - - - X

Insl A+B, + B-Cur.

- Phe Leu
- Val Cys
- AspN Gly
- GluN Ser
- His His
- Leu Leu
- Cys Val
- ~~Cys~~ Gly Glu
- Ser Ala
- His Leu
- Leu Tyr
- Val Leu
- Glu Val
- Ala Cys
- Leu Gly
- Tyr Glu
- Leu Arg
- Val Gly
- Cys Phe
- Gly Phe
- Glu Tyr
- Arg Thr
- Gly Pro
- Phe Lys
- Phe Ala

- Gly Cys
- Isol Cys
- Val Ala
- Glu Ser
- GluN Val
- Cys Cys
- Cys Ser
- Ala Leu
- Ser Tyr
- Val GluN
- Cys Leu
- Ser Glu
- Leu AspN
- Tyr Tyr
- GluN Cys
- Leu AspN

~~Glu~~

~~AspN~~

- Ser His
- Tyr Phe
- Ser Arg
- Met TRY
- Glu Gly
- His Lys
- Phe Pro
- Arg Val
- TRY Gly
- Gly Lys
- Lys Lys
- Pro Arg
- Val Arg
- Gly Pro
- Lys Val
- Lys Lys
- Arg Val
- Arg Tyr
- Pro Pro
- Val Ala

- Pro Asp
- Ala GluN
- Asp Ala
- GluN Phe
- Leu Pro
- Ala Leu
- Glu Glu
- Ala Phe

Val Ala
Leu AspN
Gly Pro
Arg Val
Ala Leu
Lys Lys

Total 6

doubles ~~[illegible]~~ 7+1

Artificial Sequences

made from the amino acids in insulin (A+B) + β-corticotropin (- Gly Glu Asp).

Total. 30 + 21 + 25 + 11

14 Ala. Leu. Val. Ser. Phe. Gly. Arg. Tyr. Leu. Lys. Tyr. Lys. Cys. Leu.

16 AspN. Gly. Cys. Ala. Met. Gly. Ser. Gly. GluN. Isol. Glu. Ala. Ala. Val. Cys. Arg.

30

16 Val. GluN. Leu. [GluN. Tyr. Leu] Arg. Val. Val. Glu. Glu. Thr. Pro. Cys. Phe. Gly.

5 Val. Tyr. Glu. Pro. Asp

21

16 Leu. His. Asp. Ser. Ala. Leu. Lys. His. Cys. AspN. Glu. Tyr. Pro. Gly. Arg. Phe.

9 Lys. Ser. Ala. TRY. [GluN. Tyr. Leu]. Cys. Pro.

25

11 Glu. Pro. Val. Phe. Val. Lys. His. Glu. Ser. Phe. Phe.

Ala Leu
Ser Phe
Phe Gly
Gly Arg
Tyr Leu x 3
Leu Lys
GluN Tyr
Glu Pro

Lys His
Ser Ala

10+1 = 11 !

doubles - Ala Ala
Val Val
Glu Glu
Phe Phe
~~Glu Glu~~

4 !

Lys Tyr Lys
Gly Ser Gly
GluN Leu GluN
Val Phe Val.

4!

numbers exactly as in the actual sequence !!!!.

ie could be random.

near near nearer. X - - X

Phe GluN
Val His
AspN Leu
GluN Cys
His Gly
Leu Ser
Cys His
Gly Leu
Ser Val
His Glu
Leu Ala - 2
Val Leu - 2
Glu Tyr
Ala Leu - 2
Leu ~~Tyr~~ Val
Tyr Cys
Leu Gly
Val Glu
Gly ~~Cu~~ Gly
Glu Phe
Arg Phe
Gly Tyr
Phe Thr
Phe Pro
Tyr Lys
Thr Ala

Gly Glu
Isol. GluN
Val Cys.
Glu Cys 2 ←
GluN Ala
Cys Ser
Cys Val
Ala Cys
Ser Ser
Cys Tyr
Ser GluN
Leu Leu
Tyr Glu 2 ←
GluN AspN
Leu Tyr
Glu Cys
AspN AspN

Ser Met
Ser His
Met Phe
Glu Arg
His Try
Phe Gly
Arg Lys 2 ←
Try Pro
Gly Val
Lys Gly
Pro Lys
Val Lys
Gly Arg
Lys Arg
Lys Pro 2 ←
Arg Val
Pro Val
Val Tyr
~~Lys f~~
Val Ala
Asp Ala
GluN Glu
Leu Ala
Ala Phe
Glu Pro.
~~Ala Leu~~
Phe Glu
Pro Phe

total ?

Art. Seq

X - X

· Ala Val
· Leu Ser
· Val Phe
· Ser Gly
· Phe Arg
· Gly Tyr
· Arg Leu
· Tyr Lys
· Leu Tyr
· Lys Lys
· Tyr Cys
· Lys Leu
· Cys AspN
· Leu Gly
· AspN Cys
· Gly Ala
· Cys Met
· Ala Gly
· Met Ser
· Gly ~~Cy~~ Gly
· Ser GluN
· Gly Isol
· GluN Glu
· Isol · Ala
· Glu Ala
· Ala Val
· Ala Cys
· Val Arg

· Val Leu
· GluN GluN
· Leu Tyr
· GluN Leu
· Tyr Arg
· Leu Val
· Arg Val
· Val Glu
· Val Glu
· Glu Thr
· Glu Pro
· Thr Cys
· Pro Phe
· Cys Gly
· Phe Val
· Gly Tyr
· Val Glu
· Tyr Pro
· Glu Arg
2

· Leu Asp
· His Ser
· Asp Ala
· Ser Leu
· Ala Lys
· Leu His
· Lys Cys
· His AspN
· Cys Glu
· AspN Tyr
· Glu Pro
· Tyr Gly
· Pro Arg
· Gly ~~Arg~~ Phe
· Arg ~~Phe~~ Lys
· Phe ~~Lys~~ Ser
· Lys ~~Ser~~ Ala
· Ser ~~Ala~~ TRY
· Ala GluN
· TRY Tyr
· GluN Leu
· Tyr Cys
· Leu Pro

· Glu Val
· Pro Phe
· Val Val
· Phe Lys
· Val His
· Lys Glu
· His Ser
· Glu Phe
· Ser Phe

Ala Val		Leu Ala	
Leu Tyr		Lys GluN	
Val Glu +		Val Glu Tyr	
Gly Tyr	Lys Val		
Tyr Cys		Lys Leu	
GluN Leu	Tyr Tyr }		
Glu Pro	Thr Tyr		10½ 8½
Pro Phe	Cys Val.		8
Total 8 + 1 = 9			27 ~9

darker = 4

Thus for c shell sphere

$$\int_{r_1}^{r_2} 4\pi r^2\, dr \;\frac{\sin(2\pi r Z)}{2\pi Z}$$

now $\int x^2 \sin x \, dx = 2x \sin x - (x^2-2)\cos x$

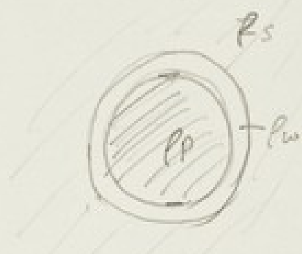
put $2\pi r Z = x$

ie $Z = \frac{1}{2r}$

Then $\int_{2\pi Z r_2}^{2\pi Z r_1} \frac{x^2}{\pi Z} \cdot \frac{\sin x}{2\pi Z} \frac{dx}{2\pi Z}$

$4\pi r^2 \delta r \quad \delta Z$

$\frac{x}{2} = r^2 - Z^2$



$(\rho_p - \rho_s)$ sphere $\sim (\rho_s - \rho_w)$ shell

= 1 3

116
83
33

.43
.405
.025

.43
.355
.035

x - x (for insulin A+B + β-cort.)

· Phe AspN
· Val GluN
· AspN His
· GluN Leu
· His Cys
· Leu Gly
· Cys Ser
· Gly His
· Ser Leu
· His Val
· Leu Glu
· Val Ala
· Glu Leu
· Ala Tyr
· Leu Leu
· Tyr Val
· Leu Cys
· Val Gly
· Cys Glu
· Gly Arg
· Glu Gly
· Arg Phe
· Gly Phe
· Phe Tyr
· Phe Thr
· Tyr Pro
· Thr Lys
· Pro Ala

· Gly Val
· Isol Glu
· Val GluN
· Glu Cys
· GluN Cys
· Cys Ala
· Cys Ser
· Ala Val
· Ser Cys
· Val Ser
· Cys Leu
· Ser Tyr
· Leu GluN
· Tyr Leu
· GluN Glu
· Leu AspN
· Glu Tyr
· AspN Cys
· Tyr AspN

· Ser Ser
· Tyr Met
· Ser Glu
· Met His
· Glu Phe
· His Arg
· Phe TRY
· Arg Gly
· TRY Lys
· Gly Pro
· Lys Val
· Pro Gly
· Val Lys
· Gly Lys
· Lys Arg
· Lys Arg
· Arg Pro
· Arg Val
· Pro Lys
· Val Val
· Lys Tyr
· Val Pro
· Tyr Ala

· Asp Leu
· GluN Ala
· Leu Glu
· Ala Ala
· Glu Phe
· Ala Pro
· Phe Leu
· Pro Glu
· Leu - Phe

4 doubles.

5 of five.

Phe Val AspN - GluN His
Isol Glu Cys

Leu Cys Gly Ser His
Cys Ala Val
(Pro) (Isol)

His Leu Val Glu Ala
Ala

Met Glu His Phe Arg.
Ala Ala Pro.

Gly Lys Lys Arg Arg.
Lys Arg Pro.

X — — — — — X

Ins A+B, β-lact.

· Phe Cys
· Val Gly
· AspN Ser
· GluN His
· His Leu
· Leu Val
· Cys Glu
· Gly Ala
· Ser Leu
· His Tyr
· Leu Leu
· Val Val
· Glu Cys
· Ala Gly
· Leu Glu
· Tyr Arg
· Leu Gly
· Val Phe
· Cys Phe
· Gly Tyr
· Glu Thr
· Arg Pro
· Gly Lys
· Phe Ala

· Gly Cys
· Isol Ala
· Val Ser
· Glu Val
· GluN Cys
· Cys Ser
· Cys Leu
· Ala Tyr
· Ser GluN
· Val Leu
· Cys Glu
· Ser AspN
· Leu Tyr
· Tyr Cys
· GluN AspN

· Ser Phe
· Tyr Arg
· Ser TRY
· Met Gly
· Glu Lys
· His Pro
· Phe Val
· Arg Gly
· TRY Lys
· Gly Lys
· Lys Arg
· Pro Arg
· Val Pro
· Gly Val
· Lys ~~Asp~~ Lys
· Lys Val
· Arg Tyr
· Arg Pro
· Pro Ala

· Tyr Asp
· Pro GluN
· Ala Leu

· Asp Phe
· GluN Pro
· Leu Leu
· Ala Glu
· Glu Phe

Leu Leu
Cys Glu
Gly Lys
Tyr Arg
Arg Pro

Total 5

dupl. 3+1

X Phe ✓
X Val ✓
X AspN ✓
X GluN ✓
X His ✓
X Leu ✓
X Cys ✓
X Gly ✓
X Ser ✓
X Glu ✓
X Ala ✓
X Tyr ✓
X Arg ✓
X Isol. ✓
X Met ✓
X THR ✓
X Lys ✓
X Pro ✓
X Asp

Arr. Seq. X – – X

· Ala Ser
· Leu Phe
· Val Gly
· Ser Arg
· Phe Tyr
· Gly Leu
· Arg Lys
· Tyr Tyr
· Leu Lys
· Lys Cys
· Tyr Leu
· Lys AspN
· Cys Gly
· Leu Cys
· AspN Ala
· Gly Ser
· Cys Gly
· Ala Ser
· Ser Gly
· Gly GluN
· Ser Isol
· Gly Glu
· GluN Ala
· Isol Ala
· Glu Val
· Ala Cys ~~Arg~~ ·
· Ala Arg

· Val GluN
· GluN Tyr
· Leu Leu
· GluN Arg
· Tyr Val
· Leu Val
· Arg Glu
· Val Glu
· Val Thr
· Glu Pro
· Glu Cys
· Thr Phe
· Pro Gly
· Cys Val
· Phe Tyr
· Gly Glu
· Val Pro
· Tyr Asp

· Leu Ser
· His Ala
· Asp Leu
· Ser Lys
· Ala His
· Leu Cys
· Lys AspN
· His Glu
· Cys Tyr
· AspN Pro
· Glu Gly
· Tyr Arg
· Pro Phe
· Gly Lys
· Arg Ser
· Phe Ala
· Lys TRY
· Ser GluN
· Ala Tyr
· TRY Leu
· GluN Cys
· Tyr Pro

· Glu Phe
· Pro Val
· Val Lys
· Phe His
· Val Glu
· Lys Ser
· His Phe
· Glu Phe

Ala Ser
Leu Cys
Val Glu
Phe Tyr
Lys AspN
Cys Gly
Glu Phe
Gly Glu

8

2 doubles

✓ Ala ✓
✓ Leu ✓
✓ Val ✓
✓ Ser ✓
✓ Phe ✓
✓ Gly ✓
✓ Arg ✓
✓ Tyr ✓
✓ Lys ✓
✓ Cys ✓
✓ AspN ✓
✓ Met ✓
✓ GluN ✓
✓ Ileu ✓
✓ Glu ✓
✓ Thre ✓
✓ Pro ✓
✓ His ✓
✓ Asp ✓
✓ TRY ✓

Suppose one sequence were forbidden

~~the loss in~~

If sequence ~~AB~~ AC is forbidden, we loose 8 cont.

~~If sequence AA is then~~

If a deletion ~~BC~~ forbidden

C 3 4
A 1 2

2 1
4 3

AAA	BAA	CAA	DAA
AAB	BAB	CAB	DAB
AAC	⋮	⋮	⋮
AAD			
ABA			
ABB			
ABC			
ABD			
ACA			
ACB			
ACC			
ACD			
ADA			
ADB			
ADC			
ADD			

P Ad Thy O

P Gu Cy O

O Cy Gu· P

RBA 2

CCA

DDA

AB

D C

C D

CD

(32)

A - T

G - C

A - G

T - C

cant be [illegible].

Ser

A B : C D

(36)

16

G - C

T' - C'

G - C

AAA

- Gly Isol val Glu

Thr- Ser Isol Cys Ser

Tyr Ser Met Glu His T - C next to

phe Arg Try Gly Lys

? ? Asp GluN - Leu

Minimum overlap:

two positions = 1 amino acid

except for 4 cases, when the near neighbour matters

~~To start with~~ Take a the four cases the repeats AA BB CC DD,

AB BA CA DA
AC BC CB DB
AD BD CD DC

6

Then take AA,A / AA,B } as the two cases.

and AA,C / AA,D }

neighbours ~~= 12~~

(a) on the right : 12 can have all 20 neighbours

8 can have to only 10 neighbours

(b) on the left. 10 ~~..~~ can have 14 neighbours.

the other 16 . . . 14 neighbours.

~~6~~ Six
Four classes

I: AB BA / AC BC / AD BD

II: CA DA / CB DB / CD DC

III: AA, $\frac{A}{B}$ / BB, $\frac{A}{B}$

IV: CC $\frac{A}{B}$ / DD $\frac{A}{B}$

V: AA $\frac{C}{D}$ / BB $\frac{C}{D}$

VI: CC $\frac{C}{D}$ / DD $\frac{C}{D}$

Forbidden neighbours.

IV – VI, – VI

III – II, IV – II,

III – IV – IV

~~III – II~~

~~IV – I~~

V – I, V – I
III, IV
V, V

all ~~of the~~ 14 (16 - 2)

~~combinations allowed.~~

Total forbidden.

4 + 12 + 4 = 20; 12 + 4 + 4 = 20

20 + 20 + 20 + 20 = 80

Thus ~~begin with $\frac{A}{B}$~~ ~~begin with $\frac{C}{D}$~~ Allowed

I - I = 36		I - III, IV, V, VI = 48	
I - II = 36		II - - - - - 48	
II - I = 36			
II - II = 36			
144		96	

(III + IV) - I = 24
(V + VI) - II = 24
48

III - III = 4
- V = 4
8

IV - III
- V
8

V - IV = 4
- VI = 4
8 + 8 = 32

144
96
32
272
48
320 ✓ ok.

400
272
128

Thus 320 combinations allowed,
out of 400 i.e. 80% of them.

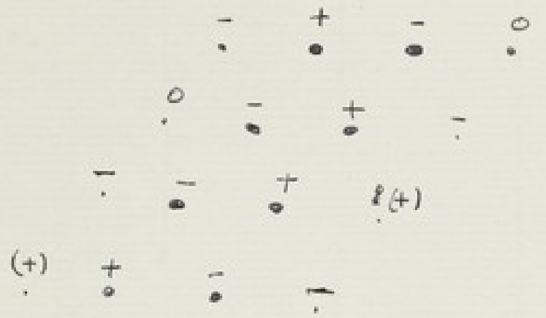
Thus seven ones should split into pairs
with complementary ~~neigh~~ sets of neighbours on one side.

Gly Met Asp?
Ala Met Lys
Ser Met Glu

Ser Ileu Cys
Ileu Asp?
Ileu Arg
Ileu Val
Ileu Glu?
Asp? Ileu

AB.

Try <u>quadruplet</u> code



Ad – Thy		A
Thy – Ad		B
Guc – Cyt.		C
Cyt – Gua		D

<u>Combination</u>

–	–	–	–	A B A B C C D D
–	–	+	–	A B B B C C C D
–	+	–	–	A A A B C D D D
–	+	+	–	A A B B C D C D
–	–	–	(+)	A B A C C C D
–	–	+	(+)	A B B C C C C
–	+	–	(+)	A A A C C D D
–	+	+	(+)	~~ABA C CCD~~ A A B C C D C
(+)	–	–	–	
(+)	–	+	–	
(+)	+	–	–	
(+)	+	+	–	

~~[illegible]~~

~~[illegible]~~

~~[illegible]~~

$A \rightleftharpoons B$

$C \rightleftharpoons D.$

ABCD

AB, AD, CB, DA, BA

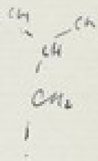
B,A B,C D,A C, B A, B

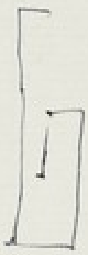
, BA, DC, CA, AB,

N   Cys - Tyr - Isol - GluN - AspN - Cys - His - Leu - Gly NH_2

oxytocin

X : Z





Ala - Glu - Glu - Asp - Asp.

Pro - Tyr - Val - Lys - Val

Pro - Val - Gly - Lys - Lys - Arg - Arg - Pro

Lys - Gly - Try - Arg - Phe - His - Glu

Pro - Val - Gly - Lys

Pro

neighbours   BCB+Y

1

ACBD

BDCD

4 chain   4 chain

+ + +
- - -

+ + +
+ +
+

+

16

ABC
BCD
CDA
DAB

AAA
BBB
CCC
DDD

Phe 6

Val 8

AspN 3

GluN 4

His 3

Leu 8

Cys 6

Gly 6 +1

Ser 5

Ala 6

Tyr ~~7~~6

Glu 7~~6~~ +1

Arg ~~8~~4

Thr 1

Pro 5

Lys 5

Isol 1

Asp 1 +1

Try 1

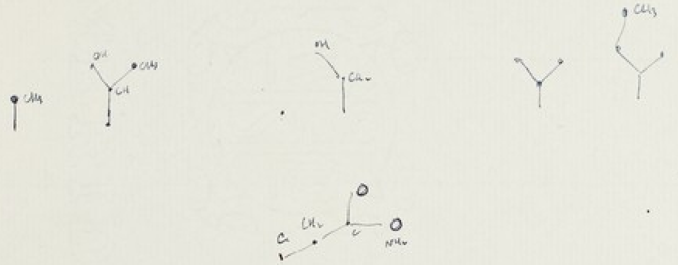
Met 1

8~~8~~ +3 ✓
7

Leu
8 Val
Glu
—
7 Gly
—
Phe
Cys
6 Ala
Tyr
—
Ser
5 Pro
Lys
Arg
4 GluN
—
3 AspN
His
—
2 Asp
Thr
Isol
1 Try
Met
—

Phe. Val. AspN. GluN. His Leu Cys ~~Gly~~ Gly Ser His Leu Val Glu Ala Leu Tyr Leu Val Cys Gly Glu Arg Gly Phe Phe Tyr Thr. Pro. Lys. Ala

Ala Lys Pro Thr Tyr Phe Phe Gly Arg Glu Gly Cys Val Leu Tyr Leu Ala Glu Val Leu His Ser Gly Cys Leu His GluN AspN Val Phe



Leu Lys = r

Phen ~~arg~~ Arg in S

∴ Lys Lys Arg Arg.

ADCBAD

!!!

∴ Val in S ~~cx~~ ∴ impossible

~~Lys~~

Leu Tyr. Leu.

Ser Tyr. Ser

Val Lys Val

Ala Glu Ala

—	Phe	Val	Aps^{NH_2}	Glu^{NH_2}
Tyr	Leu	Val	Cys.	Gly
His	Leu	Val	Glu	Ala
Gly	Isol.	Val	Glu	Glu^{NH_2}
Ala	Ser	Val	Cys.	Ser
Lys	Pro	Val	Gly	Lys
Arg	Pro	Val	Lys	Val
Val	Lys	Val	Tyr	Pro
(8)	6	8	6	7

Glu^{NH_2}	His	Leu	Cys	Gly
Ser	His	Leu	Val	Glu
Glu	Ala	Leu	Tyr	Leu
Leu	Tyr	Leu	Val	Cys.
Cys	Ser	Leu	Tyr	Glu^{NH_2}
Tyr	Glu^{NH_2}	Leu	Glu	Asp^{NH_2}
Asp	Glu^{NH_2}	Leu	Ala	Glu?
Phe	Pro	Leu	Glu?	Phe
8	6	8	5?	7

Glu	Ala	Leu	Tyr	Leu	Val	Cys
Gly	Phe	Phe	Tyr	Phe	Pro	Lys
Cys	Ser	Leu	Tyr	Glu^{NH_2}	Leu	Glu
Leu	Glu	Asp^{NH_2}	Tyr	Cys	Asp^{NH_2}	—
—	—	Ser	Tyr	Ser	Met	Glu?
~~His~~	~~Phe~~	~~Arg ?~~				
Val	Lys	Val	Tyr	Pro	Ala	?
		(6)	5	6	6	6

Leu	Cys	Gly	Ser	His
Val	Cys	Gly	Glu	Arg
Glu	Arg	Gly	Phe	Phe
—	—	Gly	Isol	Val
Arg	Try	Gly	Lys	Pro
Pro	Val	Gly	Lys	Lys
	4	6	5	

Leu	Val	Glu	Ala	Leu
Cys	Gly	Glu	Arg	Gly
Isol	Val	Glu	GluN	Cys
GluN	Leu	Glu	AspN	Tyr
Ser	Met	Glu	His	Phe
Leu	Ala	Glu	Ala	Phe
Pro	Leu	Glu	Phe	—
6	5	7	6	5

Cys	Gly	Ser	His	Leu
Cys	Ala	Ser	Val	Cys
(Cys	Phe	Ser	Isol.	Cys)
Val (Glu)	Cys	Ser	Leu	Tyr
–	–	Ser	Tyr	Ser
Ser	Tyr	Ser	Met	Glu
4	(6)	6	6	5

Val	Glu	Ala	Leu	Tyr
Pro	Lys	Ala	–	–
Cys	Cys	Ala	Gly Ser	Val
Tyr	Pro	Ala	?	?
Glu NH2	Leu	Ala	Glu	Ala
Ala	Glu?	Ala	Phe	Pro
6	5?	6	(6)	(6)

does Asp occur?

Total pairs 20
29
34
83 × 256/400 = 53 ∴ should have 30 repetitions.

we have His Leu (Cys Val) Val Glu Glu/Ala
Glu NH2 Leu (Glu Ala) Glu Ala Leu/Phe
Leu Val Glu/Cys Cys Gly Ser/Glu
Leu Tyr (NH2 Glu Leu) ~~Asp Glu~~ NH2
Leu Glu NH2/Phe Gly Lys Pro/Lys = ~~12~~ 11 which seem very few.
Pro Val (Gly Lys)
Val Cys Gly/Ser no triples

Leu	3 + 2
Val	2 + 2
Glu	1 + 1
Gly	1 + 1

~~Pro~~ Val
~~Phe~~ ~~Leu~~
~~Met~~ ~~Cys~~
~~Try~~ ~~Gly~~
~~Asp~~ Ser
~~Glu~~ ~~Pro~~
~~Asp~~ ~~Tyr~~
~~Glu~~ ~~Arg~~
~~His~~ Ala
~~Lys~~ Isoleu

-	-	Phe	Val	AspN
Arg	Gly	Phe	Phe	Tyr
Gly	Phe	Phe	Tyr	Thr
Glu	His	Phe	Arg	TRY
Glu	Ala	Phe	Pro	Leu
Leu	Glu	Phe	-	-
4	5	6	5	5

His	Leu	Cys	Gly	Ser
Leu	Val	Cys	Gly	Glu
Glu	GluN	Cys	Cys	Ala Thr
GluN	Cys	Cys	Ala Pro	Ser Gly
Ser Gly	Val Ileu	Cys	Ser	Leu
Asp	Tyr	Cys	AspN	-
6+1	(5+1)	6	(5+1)	~~[illegible]~~ (4+2)

Tyr	Thr	Pro	Lys	Ala
Gly	Lys	Pro	Val	Gly
Arg	Arg	Pro	Val	Lys
Val	Tyr	Pro	Ala	?
Ala	Phe	Pro	Leu	Glu
5	5	5	4	4??

Thr	Pro	Lys	Ala	-
TRY	Gly	Lys	Pro	Val
Val	Gly	Lys	Lys	Arg
Gly	Lys	Lys	Arg	Arg
Pro	Val	Lys	Val	Tyr
5	4	5	5	3

Gly	Glu	Arg	Gly	Phe
His	Phe	Arg	TRY	Gly
Lys	Lys	Arg	Arg	Pro
Lys	Arg	Arg	Pro	Val
3	4	4	4	4

Val	Asp	GluN	His	Leu
Val	Glu	GluN	Cys	Cys
Leu	Tyr	GluN	Leu	Glu
?	Asp	GluN	Leu	Ala
2??	3	4	3	4

[illegible] [illegible] A 6
B 6
C 5
D 3

[illegible], [illegible] A 9
B 7
C 4
D 0

CAC.

~~CACCBC~~

~~5~~

CACDDC	2 × ~~4~~	= ~~13~~ 8
CACCAC	5 × 3	= 15
CACCAD	5 × 4	= 20
CACDAC	2 × 4	= 8
~~CACDAD~~		
CACAAC	5 × 3	= 15
CACAAD	5 × 4	= 20
CACCBC	5 × 3	= 15
CACCBD	5 × 4	= 20
~~CACCBA~~		
CACDBC	2 × 4	= 8
~~CACDBD~~		
CACDBA	2 × 9	= 18
CACABC	5 × 3	= 15
CACABD	5 × 4	= 20
~~CACABA~~		
CACBBC	5 × 3	= 15
CACBBD	5 × 4	= 20
~~CACBBA~~		

100
60
42
202 [illegible] [illegible] !

ABB, ABB

~~[illegible]~~ ABA, ABA,

ACA, ACA,

ACB, ACB,

ACC, ACC

BCA, BCA

BCB, BCB,

BCC, BCC   le triple impossible

ADA, ADA,

ADB, ADB,

ADC, ADC,

ADD, ADD

BDA, BDA

BDB, BDB

BDC, BDC

BDD, BDD

CDA, CDA

CDB, CDB

CDC, CDC ?

CDD, CDD

Griffith code

$$\left| A\ B\ \begin{smallmatrix}A\\B\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}A\\B\end{smallmatrix}\ C\ \begin{smallmatrix}A\\B\\C\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}A\\B\\C\end{smallmatrix}\ D\ \begin{smallmatrix}A\\B\\C\\D\end{smallmatrix} \right|$$

Possible Reciprocals

$$\left.\begin{array}{lll} 1 & A \leftrightarrow B & C \leftrightarrow D \\ 2 & A \leftrightarrow C & B \leftrightarrow D \\ 3 & A \leftrightarrow D & B \leftrightarrow C \end{array}\right\}$$

Try each one : thus no 2 $\left.\begin{array}{l} A \leftrightarrow C \\ B \leftrightarrow D \end{array}\right\}$

Reciprocal of is

$$\left| C\ D\ \begin{smallmatrix}C\\D\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}C\\D\end{smallmatrix}\ A\ \begin{smallmatrix}C\\D\\A\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}C\\D\\A\end{smallmatrix}\ B\ \begin{smallmatrix}C\\D\\A\\B\end{smallmatrix} \right|$$

which reversed, becomes.

$$\left| \begin{smallmatrix}C\\D\end{smallmatrix}\ D\ C \right| \quad \left| \begin{smallmatrix}C\\D\\A\end{smallmatrix}\ A\ \begin{smallmatrix}C\\D\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}C\\D\\A\\B\end{smallmatrix}\ B\ \begin{smallmatrix}C\\D\\A\end{smallmatrix} \right|$$

Thus the code and its reciprocal have in common.

ABA , CDC only. (which are ~~self~~ reciprocals)

Suppose we ~~have~~ had
BBA → DDC → CDD
and AAB   CCD   DCC
$BA\begin{smallmatrix}A\\B\end{smallmatrix}$ ~~BAB → DCD → DCD~~

Thus these must not neighbour themselves or each other:

We must now consider groups of three:

no 1 $A \leftrightarrow B \quad C \leftrightarrow D$

Respond is $\left| B A \begin{smallmatrix}B\\A\end{smallmatrix} \right| \quad \left| \begin{smallmatrix}B\\A\end{smallmatrix} D \begin{smallmatrix}B\\A\\D\end{smallmatrix}\right| \quad \left|\begin{smallmatrix}B\\A\\D\end{smallmatrix} C \begin{smallmatrix}B\\A\\D\\C\end{smallmatrix}\right|$

reversed

$\left|\begin{smallmatrix}A\\B\end{smallmatrix} A B\right| \quad \left|\begin{smallmatrix}A\\B\\D\end{smallmatrix} D \begin{smallmatrix}A\\B\end{smallmatrix}\right| \quad \left|\begin{smallmatrix}A\\B\\C\\D\end{smallmatrix} C \begin{smallmatrix}A\\B\\D\end{smallmatrix}\right|$

Ran. $\begin{smallmatrix}A\\B\end{smallmatrix} C \begin{smallmatrix}A\\B\end{smallmatrix}$; 4

respond

$\begin{smallmatrix}A\\B\end{smallmatrix} D \begin{smallmatrix}A\\B\end{smallmatrix}$; 4

ABA, ABA

ABB, ABB

ACA, ACA

ACB, ACB

ACC, ACC

BCA, BCA

BCB, BCB

BCC, BCC

ADA, ADA

ADB, ADB

ADC, ADC

ADD, ADD

[illegible]

~~ABA, ABA~~ BBA, BDA

~~ABB, ABB~~ BDB, BDB

~~ABC, ABC~~ BDC, BDC

~~ABD, ABD~~ BDD, BDD

CDA, CDA

CDB, CDB

CDC, CDC

CDD, CDD

no 3

$A \leftrightarrow D$ t
$B \leftrightarrow C$

$\left| D\,C \begin{smallmatrix} D \\ C \end{smallmatrix} \right| \quad \left| \begin{smallmatrix} D \\ C \end{smallmatrix}\, B \begin{smallmatrix} D \\ C \\ B \end{smallmatrix} \right| \quad \left| \begin{smallmatrix} D \\ C \\ B \end{smallmatrix}\, A \begin{smallmatrix} D \\ C \\ B \\ A \end{smallmatrix} \right|$

reverse $\left| \begin{smallmatrix} C \\ D \end{smallmatrix}\, C\, D \right| \quad \left| \begin{smallmatrix} C \\ B \\ D \end{smallmatrix}\, B \begin{smallmatrix} C \\ D \end{smallmatrix} \right| \quad \left| \begin{smallmatrix} A \\ C \\ B \\ D \end{smallmatrix}\, A \begin{smallmatrix} B \\ C \\ D \end{smallmatrix} \right|$ no reciprocals

---

ABA, ABA
ABB, ABB

ACA, ACA
ACB, ACB
ACC, ACC
BCA, BCA
BCB, BCB
BCC, BCC

ADA, ADA
ADB, ADB
ADC, ADC
ADD, ADD
BDA, BDA $\therefore$ no triples
BDB, BDB
BDC, BDC
BDD, BDD
CDA, CDA
CDB, CDB
CDC, CDC
CDD, CDD

A B	A B	A B C	A B C	A B C D	A B C D

Stimulation

discrimination

	A	B	C	D
A	none	ABA ABB	ACA ACB ACC	ADA ADB ADC ADD
B	ABA	ABB	BCA BCB BCC	BDA BDB BDC BDD
C	ACA BCA	ACB BCB	ACC BCC	CDA CDB CDC CDD
D	ADA BDA CDA	ADB BDB CDB	ADC BDC CDC	ADD BDD CDD

12
18
8
2
40 ✓

~~AAAA~~ 2
~~ABBB~~
~~AABB~~
ABAB

A B B B
C C C
D D D

AAAA	1	0
BBBB	1	0
ABBB	4	1
BAAA	4	1
AABB	4	1
ABAB	2	0
	16	3

ABBB
AAAB
AABB
~~ABAB~~

ACCC
AAAC
AACC

~~BCCC~~
BBBC
~~BBCC~~

CBBB
CCCB
CCBB

A A A
A B B B | 1 | A A A A
B B B B
C C

4
ABAB

AA
A ~~AB~~

A A A A
A B B B | A B B B

1

AC
BC

ABAB

BACA

~~ABBB~~
~~BAAA~~
A ~~ABB~~

A ~ G

A ~ U
G ~ C

U ~ C

A G U C

A B C
C B
D D

16 Save
20
20 + reserve

	A	B	C	D
A	none 0 ~~none~~ none 0 none 4	5 + 0 5 7 + 0 7 5	2 + 0 2 5 + 0 5 5 ~~[illegible]~~	5 + 0 5 6 + 0 6 5 ~~[illegible]~~
B	$5 + \frac{1}{2}$ 5.5 6 + 1.4 7.4 5.1	$3 + \frac{3}{4}$ 3.7 3 + 3.1 6.1 6.5	~~none~~ 3 + 0 3 4 + 0 4 5	~~[illegible]~~ $3 + \frac{3}{4}$ 3.7 3 + 2.5 5.5 5.5
C	none 0 3 + 0.8 3.8 3.8 ~~[illegible]~~	0 + 2 2 1 + 2.4 3.4 4.7 ~~[illegible]~~	8 + 0 8 8 + 0 8 4	0 + 2 2 0 + 2.8 2.8 5.1
D	$5 + \frac{1}{2}$ 5.5 5 + 1 6.0 4.7	$3 + \frac{3}{4}$ 3.7 3 + 2.2 5.2 5.2	3 + 0 3 3 + 0 3 5	$3 + \frac{3}{4}$ 3.7 3 + 1.8 4.8 6.5

B D C A

A
B B A
C D C
D C

no cyclic
interchange

C A A
C D
D

DDA
AAD

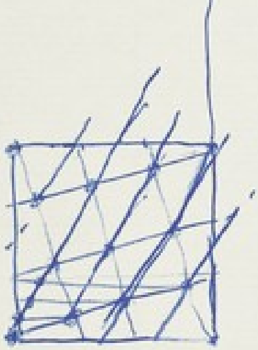
III

not C, not A not C, not A not C, not A not C

| | | |, | | | |, | | | |, | | | |,

A ~ C complimentary.

Rule may be: "not A", every fourth.



95
3
285

CODING