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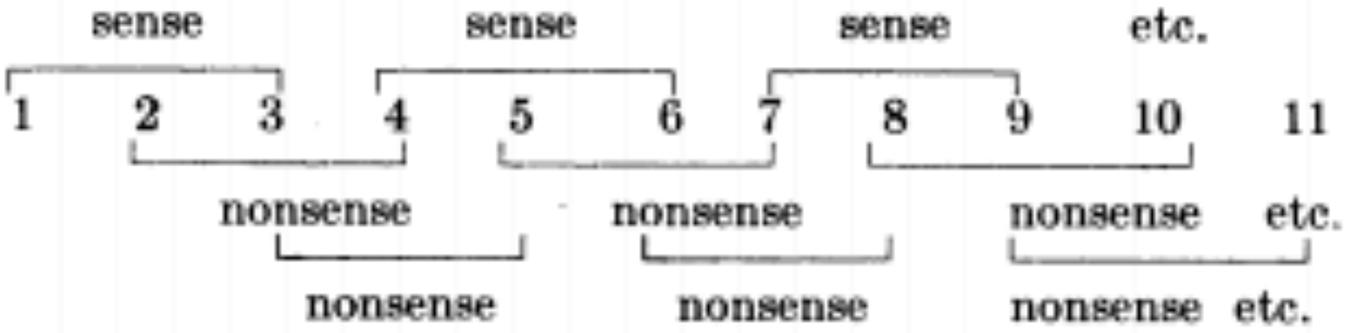

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triples          ; => ["AAA" "AAC" "AAG" "AAT" "ACA" "ACC" "ACG" "ACT"
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(def rotations
  (fn [s] (let [n (count s)]
            (map string (take n (partition n 1 (cycle s)))))))

(rotations ACGT)                          ; => ("ACGT" "CGTA" "GTAC" "TACG")

(take 7 (map rotations triples))          ; => (("AAA" "AAA" "AAA")
                                          ;     ("AAC" "ACA" "CAA")
                                          ;     ("AAG" "AGA" "GAA")
                                          ;     ("AAT" "ATA" "TAA")
                                          ;     ("ACA" "CAA" "AAC")
                                          ;     ("ACC" "CCA" "CAC")
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(set (str ACGT ACGT ACGT))                ; => #{\A \C \G \T}
[((set ACGT) \T) ((set ACGT) \Z)]         ; => [\T nil]

(def codons (set (map (comp set rotations) triples)))
(count codons)                            ; => 24
(take 4 codons)                           ; => (#{"ACC" "CCA" "CAC"}
                                          ;     #{"GGG"}
                                          ;     #{"TTT"}
                                          ;     #{"GCC" "CGC" "CCG"})

(map first (group-by count codons))       ; => (3 1)

(def sense-codons ((group-by count codons) 3))
(count sense-codons)                      ; => 20
```

Eureka!

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3

CODES WITHOUT COMMAS

This is fun programming but (as of 1961) bad biology.

**Biology is not physics and certainly not engineering.
Life's processes are rarely efficient and often messy.
(Crick and Gamow were both degreed in physics.)**

What is this program about? Can you follow it?

**This programming language is as old as this paper.
It was designed to help machines help us think.**

**It is almost the simplest language that can work.
So the program is about the world more than itself.
A programming language can be a tool of discovery
and not just the means of commanding a computer.**

**You can develop and explore a program while it runs.
And see the value of each expression as it's evaluated.
They appear here literally as the computer prints them.
("Notebook systems" like Jupyter return to this idea.)**

**How do you think with your programming language?
Does it aid or hinder your understanding of the world?**

(-: BTW: Did you notice any commas in this code? :-)

```
(take 5 sense-codons)                   ; => (#{"ACC" "CCA" "CAC"}
                                        ;      #{"GCC" "CGC" "CCG"}
                                        ;      #{"CAA" "ACA" "AAC"}
                                        ;      #{"CTC" "CCT" "TCC"}
                                        ;      #{"AGC" "CAG" "GCA"})

(def sense (map first sense-codons))
(count sense)   ; => 20
(take 7 sense)  ; => ("ACC" "GCC" "CAA" "CTC" "AGC" "TAT" "GAG")
(def nonsense (remove (set sense) (set triples)))
(count nonsense)                        ; => 44

(def code (zipmap sense (keys amino-acids)))
(sort-by second code)                   ; => (["AGC" :A]
                                        ;      ["TAA" :C]
                                        ;      ["TGT" :D]
                                        ;      ["TCA" :E]
                                        ;      ["TAT" :F]
                                        ;      ["TAG" :G]
                                        ;      ["CTG" :H]
                                        ;      ["CAA" :I]
                                        ;      ["ACG" :K]
                                        ;      ["ACC" :L]
                                        ;      ["GCC" :M]
                                        ;      ["GAA" :N]
                                        ;      ["CTA" :P]
                                        ;      ["GAT" :Q]
                                        ;      ["CTC" :R]
                                        ;      ["TCG" :S]
                                        ;      ["CTT" :T]
                                        ;      ["GTG" :V]
                                        ;      ["GAG" :W]
                                        ;      ["GGC" :Y])

(map string (take 3 (partition 3 1 strand))) ; => ("TTA" "TAA" "AAT")

(def amino-keys (map (comp code string) (partition 3 1 strand)))
(take 13 amino-keys) ; => (nil :C nil nil nil :Y nil nil :M nil nil :Y :M)

(def aminos (map amino-acids (remove nil? amino-keys)))
(take 4 aminos) ;=> ("cysteine" "tyrosine" "methionine" "tyrosine")
```

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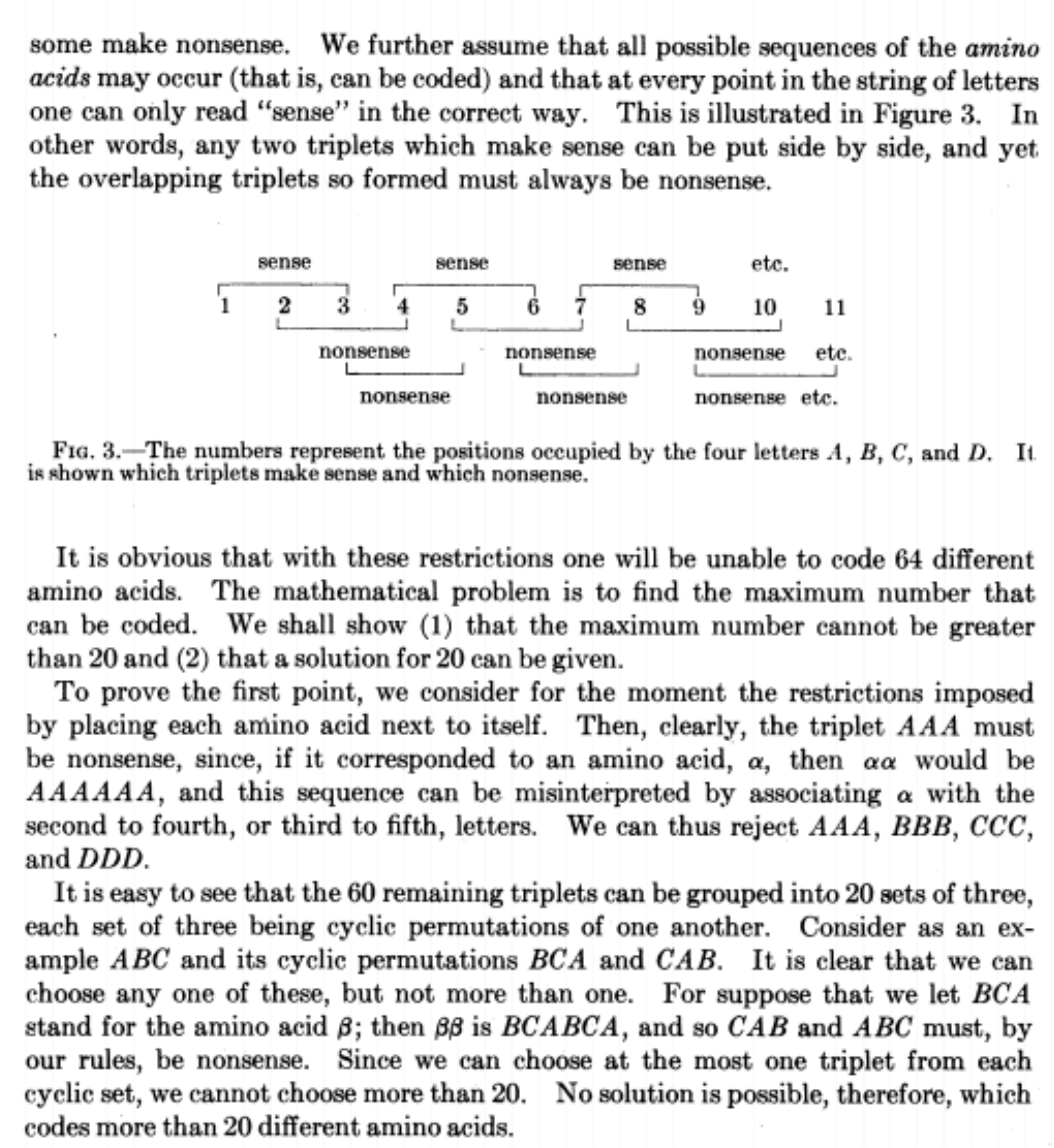
CODES WITHOUT COMMAS



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