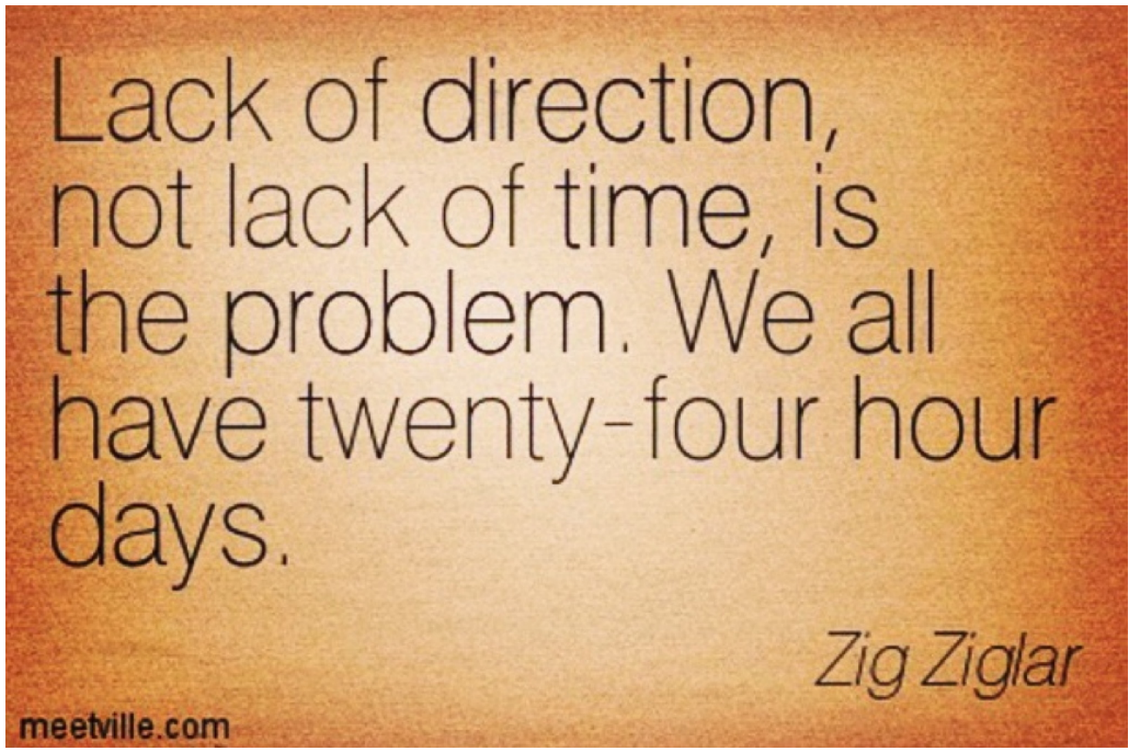
Lecture 19:

The genetic code

Course 371

Lessons for life



AIMS

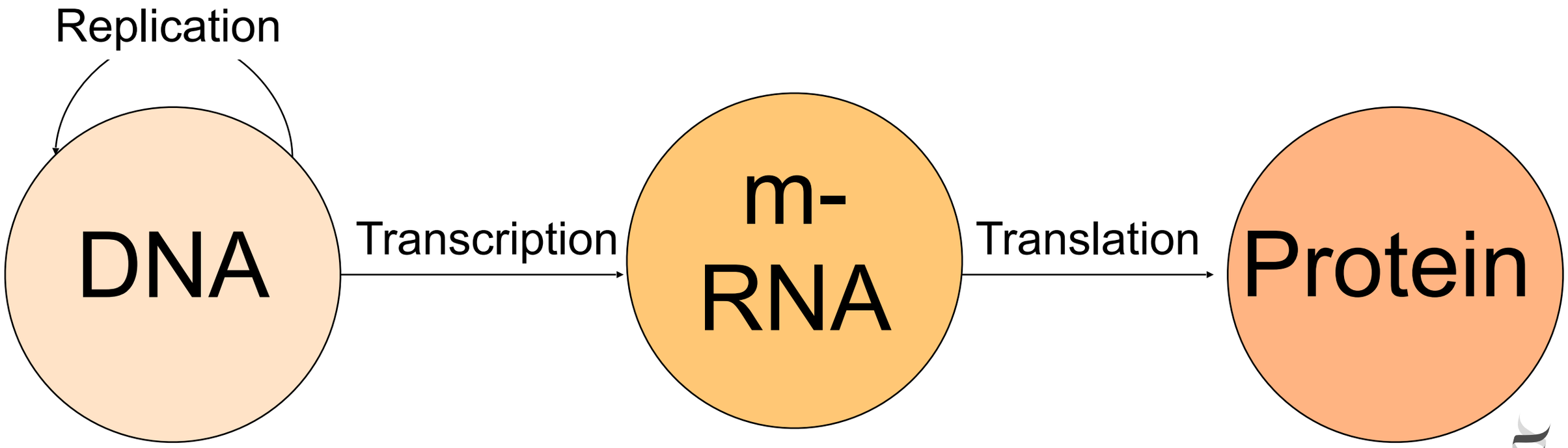
- Understand the genetic code and how it was decoded.
- Understand the codons and what do they code for.
- Understand the general characteristics of the genetic code.

Gene expression

- Translating a protein coding gene is called **gene expression.**

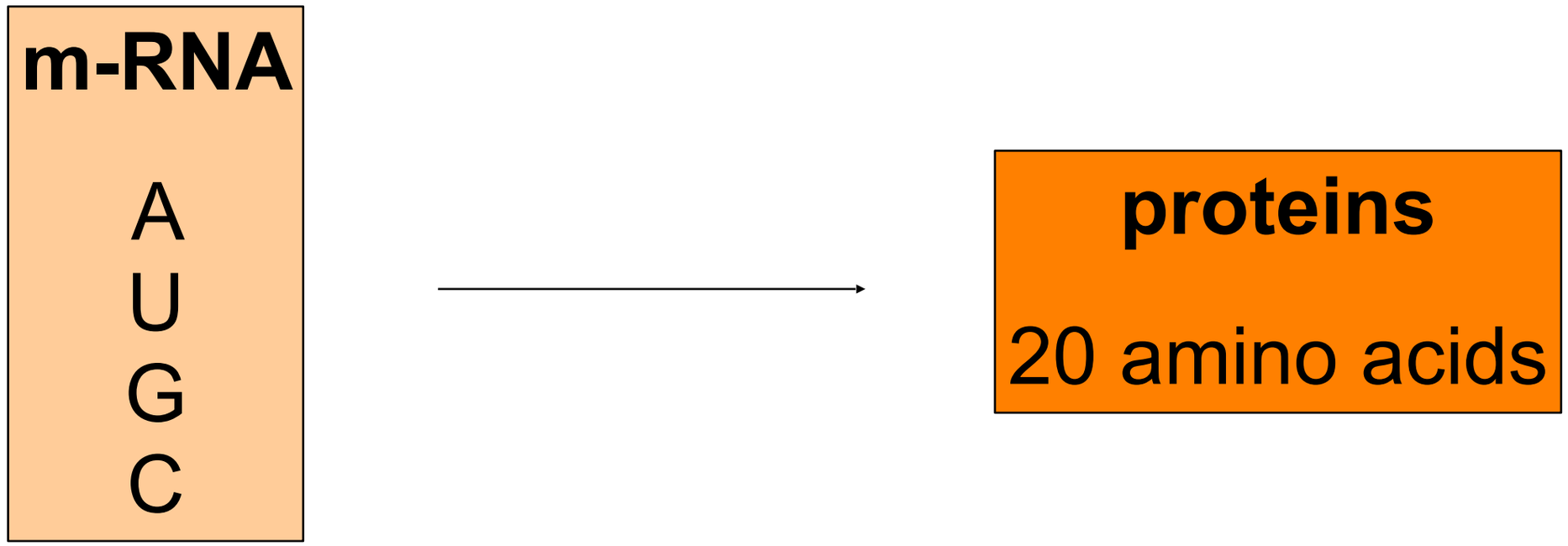
- The path from genes to proteins go through an intermediate molecule called **m-RNA.**

What molecule gets translated into a protein?



The genetic code

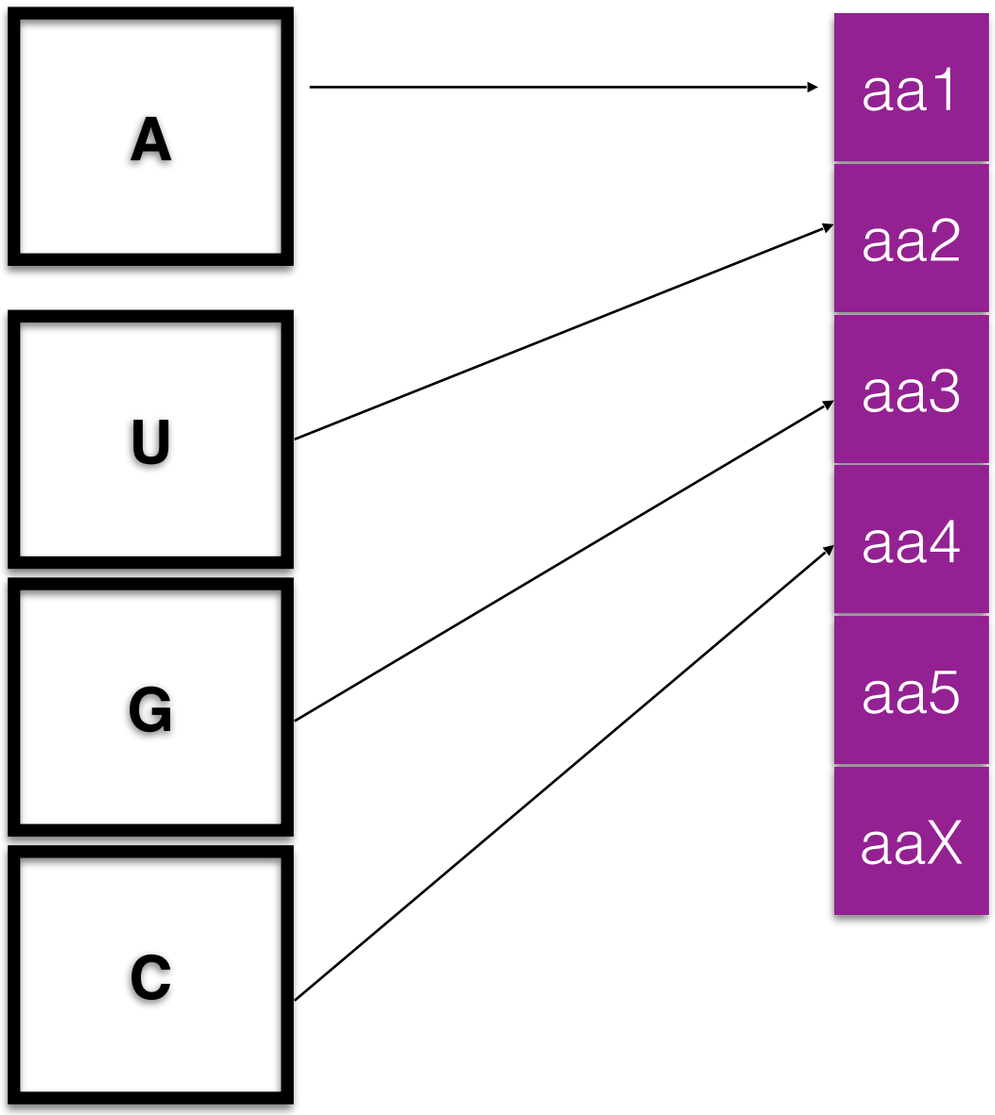
How do we get from mRNA → protein?



How do we get from 4 → 20?

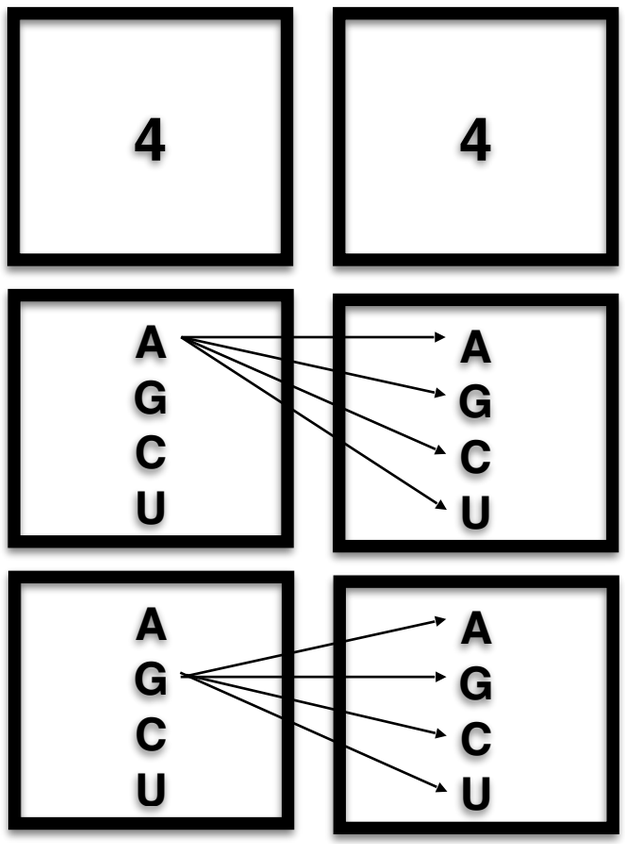
The genetic code

How do we get from mRNA → protein?



The genetic code

How do we get from mRNA → protein?



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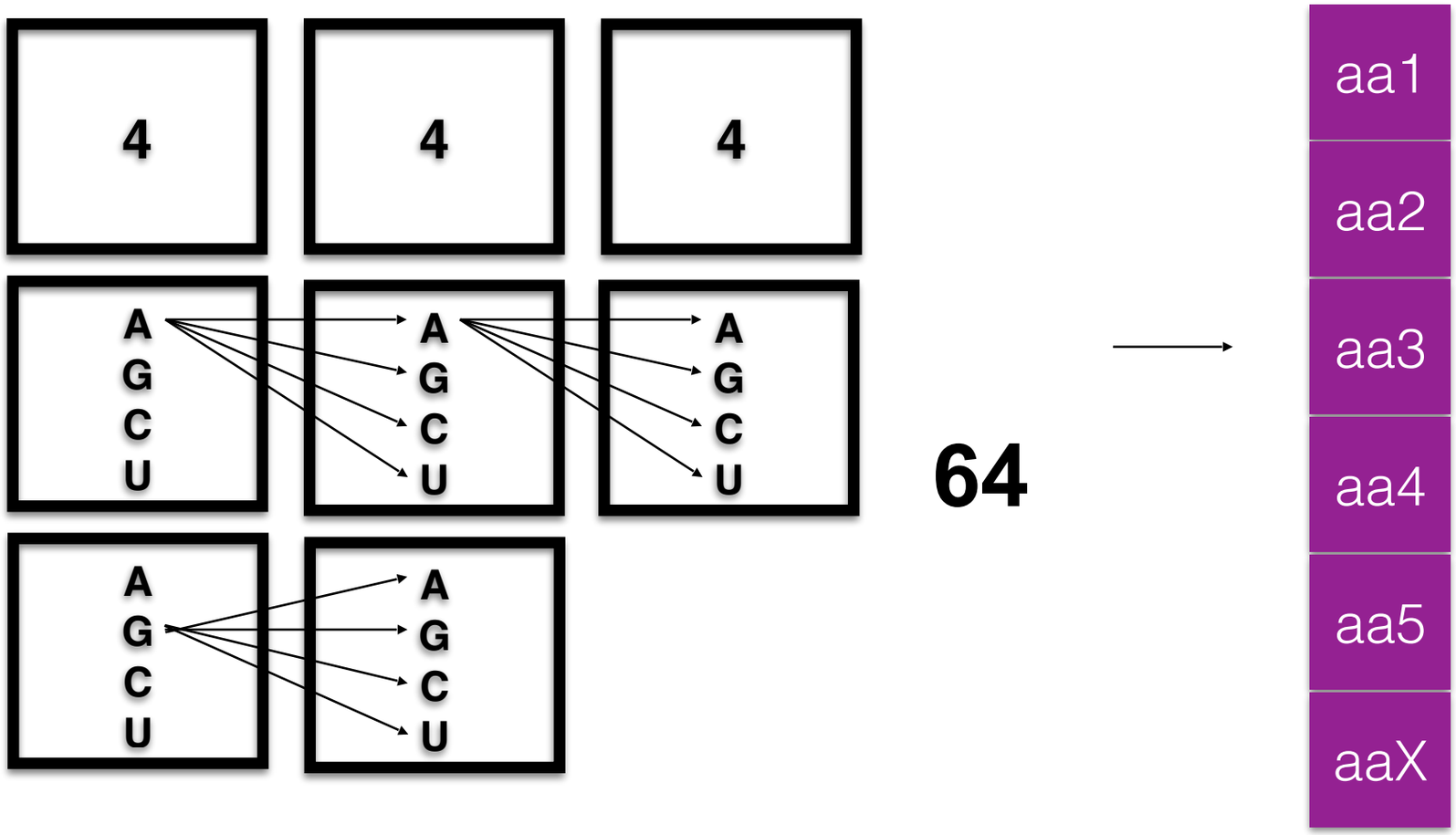
The genetic code

How do we get from mRNA → protein?



A mind experiment

- Each nucleotide codes for one amino acid.
  Does not work (4 ≠ 20)

- Each 2 nucleotide codes for one amino acid.
  How many combinations of 2 nucleotides?
  4x4 = 16 combinations
  Does not work (16 ≠ 20)

- Each three nucleotides codes for one amino acid.
  How many combinations of 3 nucleotides?
  4x4x4 = 64 combinations
  Can work (64 > 20)

A mind experiment

A code of three nucleotides coding for a single amino acid creates more than needed!

The genetic code

- The genetic code is made of triplets (3) nucleotides.
- **Codon:** three nucleotides in a m-RNA coding for a single specific amino acid.

How this was found?

The genetic code

- Mutation experiments proved that only removal or addition of nucleotides by multiple of three can result in a functional protein.

	MUTATION	PHENOTYPE
Wild-type sequence A B C A B C A B C A B C A B C A B C A B C A B C	NONE	rII+
FC0 mutant A B C A A B C A B C A B C A B C A B C A B C A B	+	rII−
Supression of FC0 A B C A A B A B C A B C A B C A B C A B C A B C	+ −	rII+
Two base additions A B C A A B C A B C B A B C A B C A B C A B C A	+ +	rII−
Three base additions A B C A A B C A B C B A B C C A B C A B C A B C	+ + +	rII+

+ Base addition
− Base deletion

حمل حسن قلم

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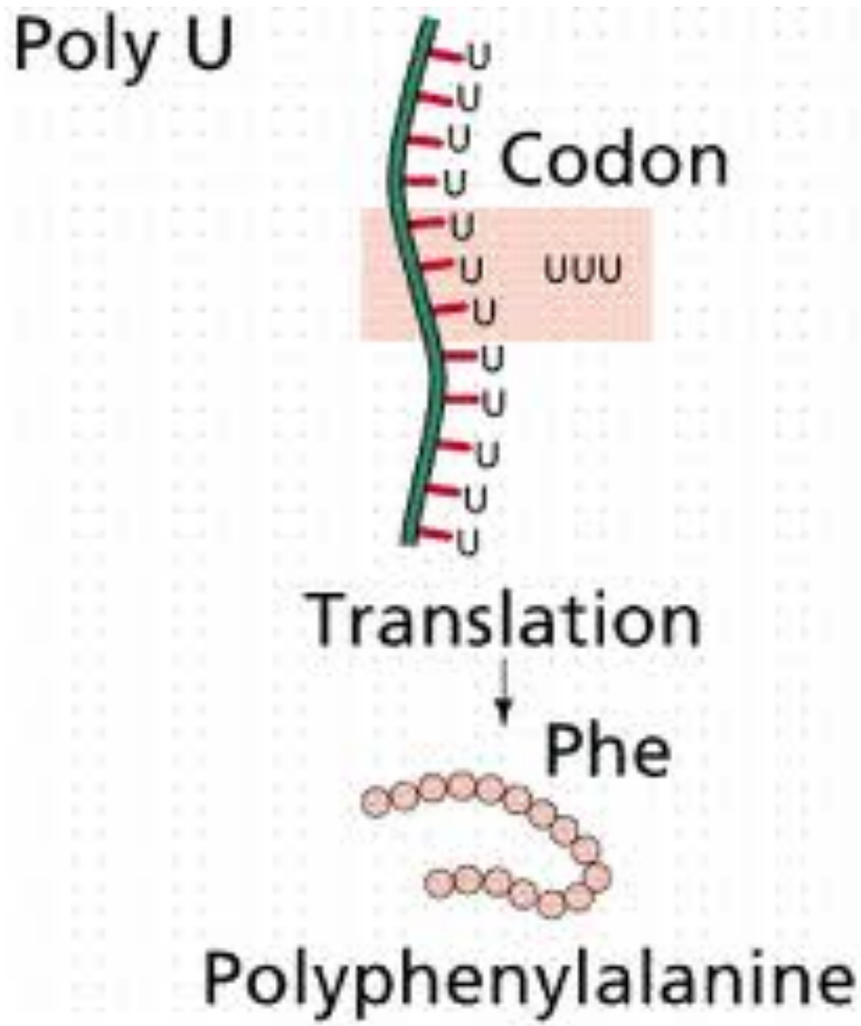
What codons code for what amino acid?

First experiment: using mononucleotide polymers as the mRNA.

Poly(U) mRNA gives poly phenylalanine amino acids. Thus **UUU** codes for **phenylalanine**.

Can we do the same for the other three nucleotides?



What codons code for what amino acid?

Poly(A) mRNA gives poly lysine amino acids. Thus **AAA** codes for **lysine**.

Poly(C) mRNA gives poly proline amino acids. Thus **CCC** codes for **proline**.

Poly(G) could not be done for structural difficulties.

What codons code for what amino acid?

Second experiment: using random copolymer mRNA of two different nucleotides.

Make a copolymer of (A and C).

What are the outcomes?

What codons code for what amino acid?

- AAA (we already know)
- CCC (we already know)

- CCA
- CAC
- AAC
- CAA
- ACC
- ACA

What do they code for?

Asparagine

Glutamine

Histidine

Threonine

How Do we know?

What codons code for what amino acid?

Second experiment: using random copolymer mRNA of two different nucleotides.

(1) Play with the ratio (add more A than C)

(2) Get more Asparagine than histidine

(3) Thus Asparagine must be coded by 2As and histidine by 2Cs

This experiment tells us about the composition of the codon rather than the sequence of the codon!

What codons code for what amino acid?

Third experiment: using copolymer of know sequence.

Using UC copolymer gives the following mRNA.

5’ UCUCUCUCUCUCUCUCUCUCUCUCUC 3’

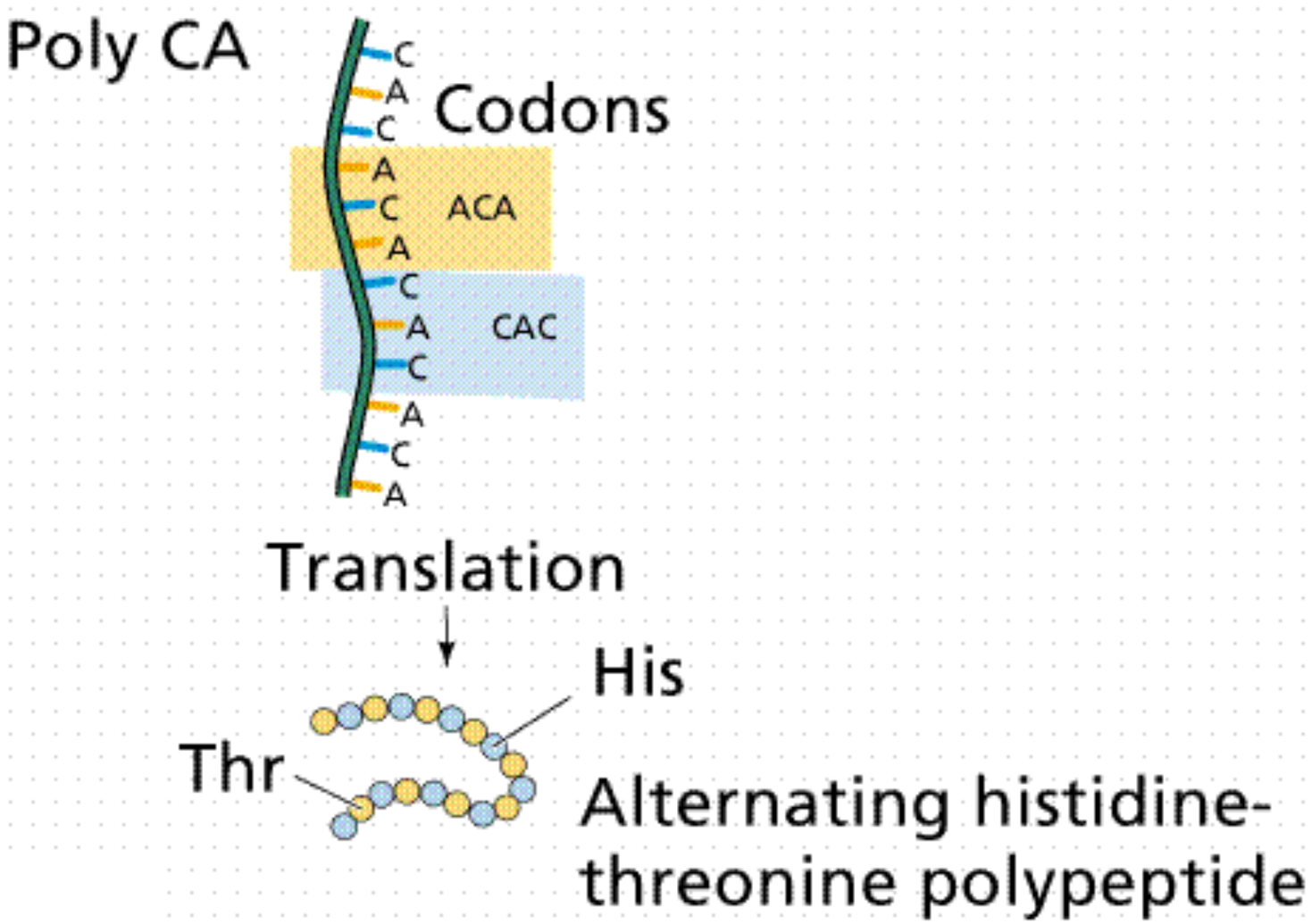
The resulting amino acid chain is

leucine-serine-leucine-serine-leucine-serine-leucine-serine

What codons code for what amino acid?

Result: UCU and CUC code for leucine and serine

But can not tell which is which!



What codons code for what amino acid?

Fourth experiment: using the translation process to determine the code.

The approached used was called "**ribosome binding assay**"

The experiment determined the specific sequence of the codons.

What codons code for what amino acid?

When decoding the mRNA codons, 1 amino acid go the ribosome and bind (tRNA).

This approach determined the sequence of the majority of the codons.

The genetic code

The genetic code is composed of 64 codons

- 61 amino acid coding codons
  - Start codon (AUG) methionine (Met)
  - 60 codons code for 19 other amino acids
- Three codons code for the stop of translation
  - UAA
  - UAG
  - UGA

The genetic code

The codons are more than what we need to translate the 20 amino acids

We will learn how and why later!

Characteristics of the genetic code

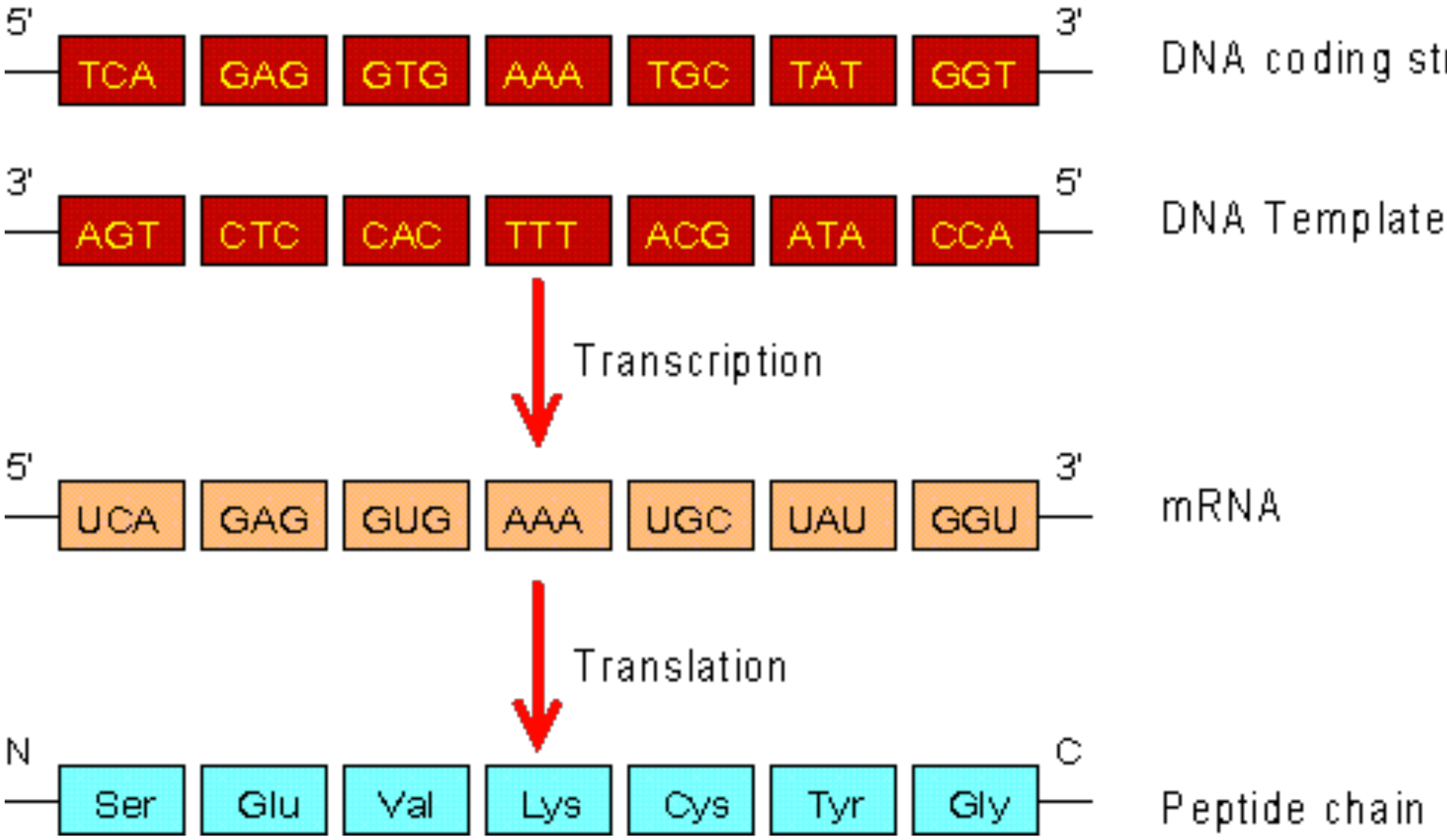
1. The genetic code is made of triplets of nucleotides (3nts) called codons.

Second letter

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

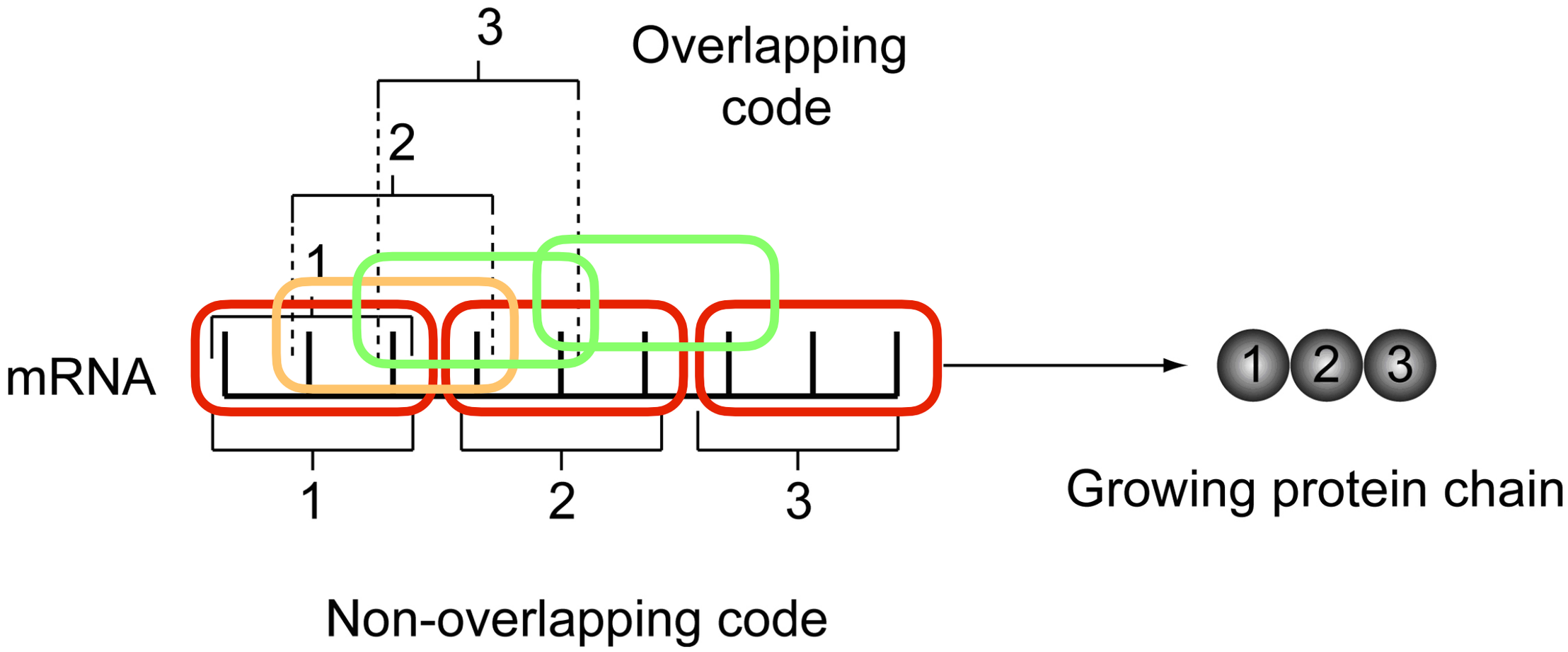
Characteristics of the genetic code

2. The genetic code is continuous (no skipping)



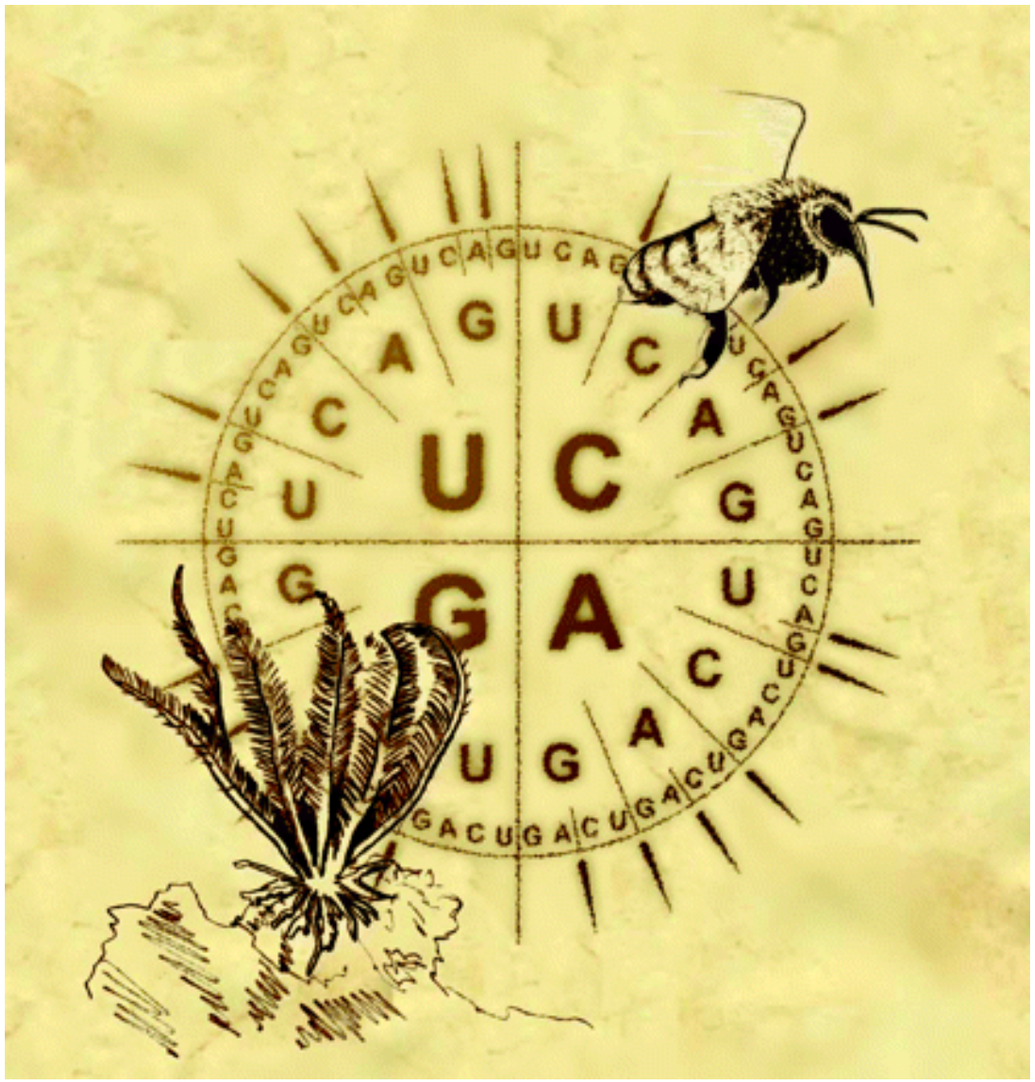
Characteristics of the genetic code

3. The code is not overlapping. Every three nucleotides in a sequence code for one codon.



Characteristics of the genetic code

4. The genetic code is universal (almost).
All living organisms have the same code and the system of the code.



Characteristics of the genetic code

5. The code has specific signals for start of translation and stop of translation.

The start codon (AUG) codes for a methionine amino acid.

Three stop codons (UAA, UAG, UGA) code for a stop **WITHOUT** and amino acid.

The stop codons are also called **nonsense codons, or chain termination codons.**

Characteristics of the genetic code

6. The genetic code is “degenerate”.

Degenerate means redundant.

Remember 61 codons code for 20 amino acids

More than one codon for the same one amino acid

Characteristics of the genetic code

أسد

حيدر

أسامة

شِبْل

ليث

غضنفر

بَاسِل

حَمْزَة

سَبُع

ضَرْغَام

Characteristics of the genetic code

أسد

حيدر

أسامة

شِبْل

ليث

غضنفر

بَاسِل

حَمْزَة

سَبُع

ضَرْغَام

هل من الممكن الإشارة للتيس مثلاً بأي من هذه الأسماء؟

Characteristics of the genetic code

أسد

حيدر

أسامة

شِبْل

ليث

غضنفر

بَاسِل

حَمْزَة

سَبُع

ضَرْغَام

لا تستخدم الاسماء هذه إلا للإشارة لل (lion) بينما ال (lion) يشار له بعدة أسماء يختص بها عن غيره

Characteristics of the genetic code

Remember:

Each codon codes for one amino acid

BUT

An amino acid can be coded by more than one codon

Characteristics of the genetic code

7. The Wobble effect of the third base in the codon

The third nucleotides in some codons are not essential for determining the identity of the amino acid.

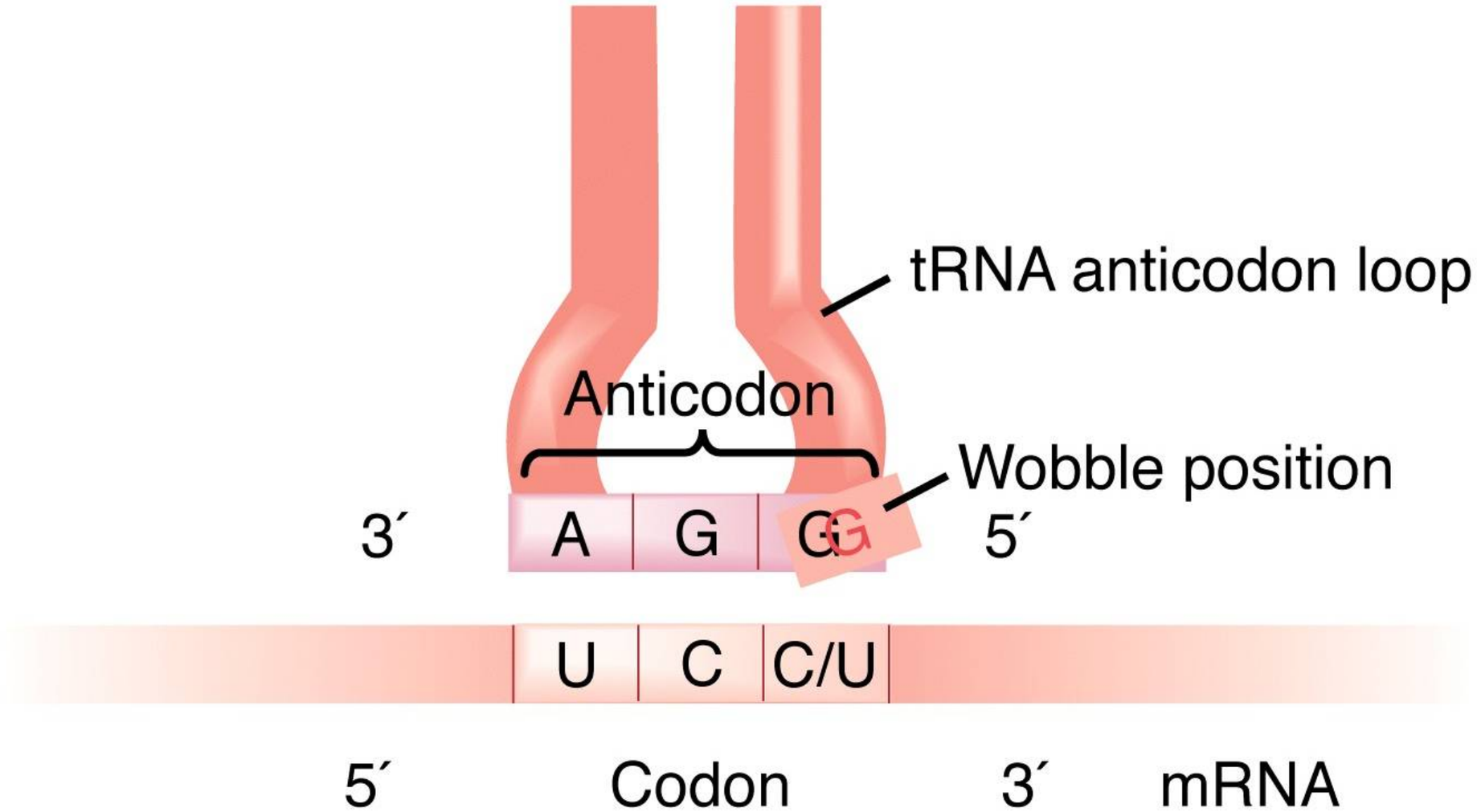
Characteristics of the genetic code

Second letter

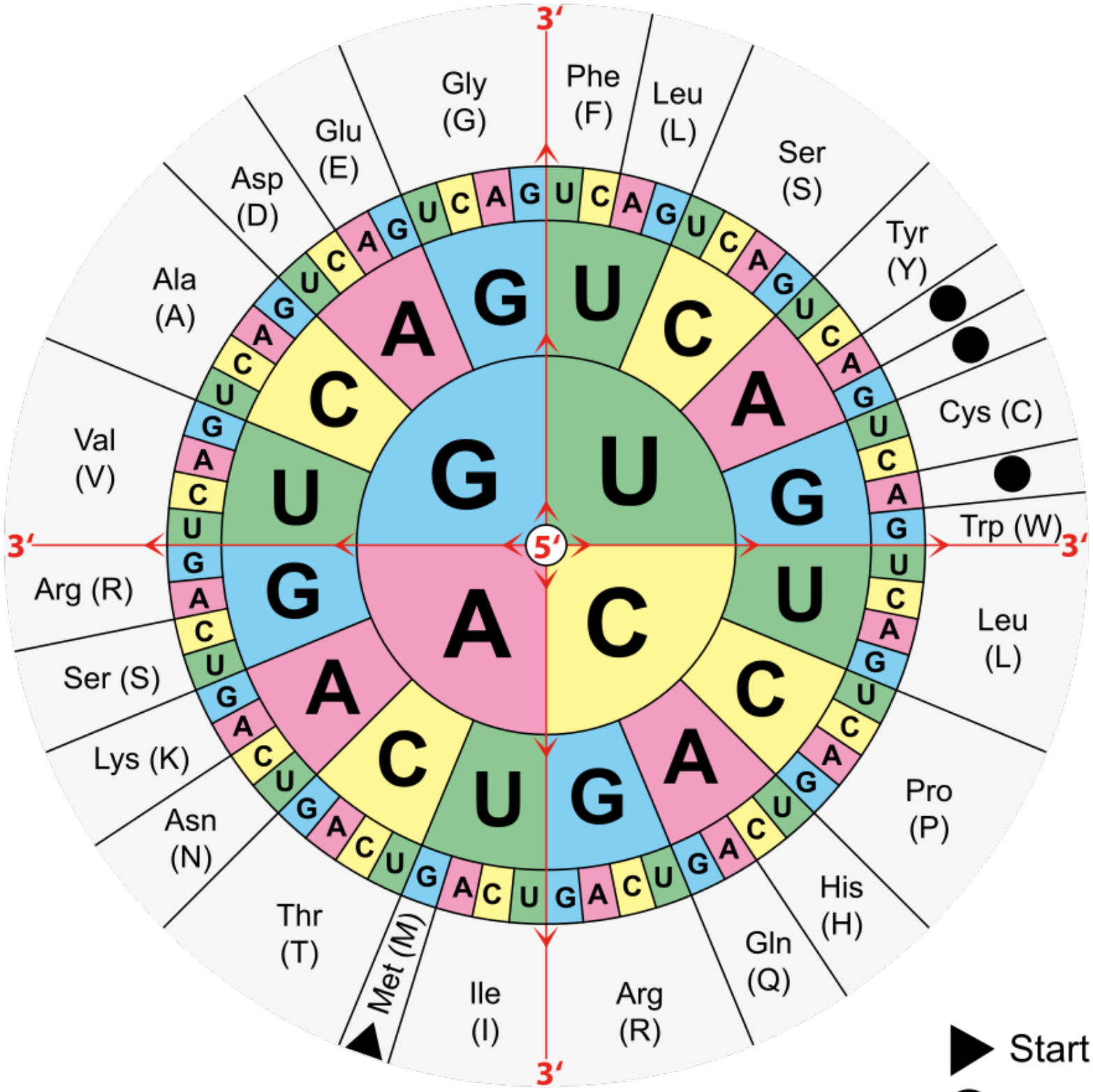
First letter	U	C	A	G	Third letter
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA: Stop UAG: Stop	UGU, UGC: Cys UGA: Stop UGG: Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile AUG: Met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

Characteristics of the genetic code

This due to the base pairing between the codon in the mRNA and the anti-codon in the tRNA during the translation process.



The genetic code



Stuff to know

Chain termination codons

Ribosome binding assay

AUG

Start codon

copolymer

UGA

codon

Polar amino acids

Nonsense codons

Mononucleotide polymer

triplets

Stop codon

UAG

Random copolymer

UUA

Expectations

- You know how the mRNA carries the genetic code and how the sequence is mean to be read.
- You understand the experiments that lead to the discovery of the genetic code.
- You know the characteristics of the genetic code.

We have to ….