Bioinformatics - 16/01/2025

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Contents

1 Antibiotic:

A mini protein/ peptide / short string of amino acids which can kill a bacterium

2 Reverse Complement

```
from Bio.Seq import Seq


dna = Seq("ATGCCGTA")
print(f"Reverse Complement: {dna.reverse_complement()}")
```

3 Peptide/ anti-biotic sequencing

1. **Replication**:
   - Initiation
   - Elongation
   - Termination
2. **Transcription**:
   - DNA ⇒ RNA
   - It's basically replacing T (Thymine) with U (Uracil)
   - To do it in Biopython:

     ```
     from Bio.Seq import Seq
     seq = Seq("AGTACACTGGT")
     seq_transcribed = seq.transcribe()
     print(f"Original: {seq}\nTranscribed: {seq_transcribed}")
     ```

3. **Translation**
   - RNA ⇒ Protein
   - Take 3 Nucleotides (A, U, G, C) at a time
   - **Codon**: A triplet of nucleotides

     Number of Codons: $4^3 = 64$
     Number of Amino Acids: 20
   - Codons **code** for an amino acid. In other word, a codon is an encoding of an amino acid.
   - A single amino acid can have multiple codons coding for it.
   - **Stop Codons**:

     UAA UAG UGA

     These basically code to stop translation.
   - To do it in Biopython:

```
from Bio.Seq import Seq
seq = Seq("AGTACACTGGTG")
seq_translated = seq.translate()
print(f"Original: {seq}\nTranslated: {seq_translated}")
```

4 NRP Synthetase

1. Stands for Nonribosomal Peptide
2. Adds one amino acid at a time.

5 Measure of Molecular weight

1. 1 Dalton (Da) = mass of a proton/ neutron
2. Mass of the molecule = sum of all the protons
3. Here's how you do it in biopython

```
from Bio.SeqUtils.ProtParam import ProteinAnalysis
analysis = ProteinAnalysis("VKLFPWFNQY")
mass = analysis.molecular_weight()
print(f"Mass: {mass}")
```

1. Table of the weights of amino acids:

G	A	S	P	V	T	C	I/L	N	D	K/Q	E	M	H	F	R	Y	W
57	71	87	97	99	101	103	113	114	115	128	129	131	137	147	156	163	186

   We have **20 amino acids**, but only **18 integer masses**.

6 Isoelectric point

- It's the pH where a molecule has 0 electric charge
- Code to find it in biopython:

```
from Bio.SeqUtils.ProtParam import ProteinAnalysis

analysis = ProteinAnalysis("VKLFPWFNQY")
isoelectric_point = analysis.isoelectric_point()
print(isoelectric_point)
```

7 Other stuff you can with ProteinAnalysis

7.1 Amino Acid Composition

```
from Bio.SeqUtils.ProtParam import ProteinAnalysis
dna = ProteinAnalysis("ATGCCGTA")

print(dna.count_amino_acids())
```

7.2 Aromaticity

```
from Bio.SeqUtils.ProtParam import ProteinAnalysis

dna = ProteinAnalysis("ATGCCGTA")
print(dna.aromaticity())
```

8 Mass Spectrometer

It's a tool used to produce a mass spectrum.

8.1 Theoretical Spectrum: Mass of every possible sebpeptide, plus 0 and the mass of the peptide

eg. Peptide Given = LNEQ Spectrum:

L	N	Q	E	LN	NQ	EL	QE	LNQ	ELN	QEL	NQE	LNQE
..	..	..	..	..	..	..	..	..	..	..	..	..

So you're given with something like `[0, 97, 99, ... 497]`.

8.2 Noisy Spectra

- **False mass**: Present in Experimental Spectrum, missing in theoretical spectrum
- **Missing mass**: Present in theoretical spectrum, missing in experimental spectrum
- **Score**: Number of masses common in both spectra.

9 Cyclopeptide Sequencing problem:

Given a theoretical spectrum, find out the peptide.

9.1 Brute Force Cyclopeptide Sequencing:

- The mass of the entire peptide is usually known.
- Algorithm:
    1. Generate all peptides with given mass.

– Say it's 1322. Find all 1-mers, 2-mers, 3-mers ... k-mers that sum up to 1322

2. Form the theoretical spectrum for each and every k-mer you generated
3. Look for matches with given spectrum.

- You may not get the old peptide back, because there can be different amino acids with the same mass, and moreover, you can have different **combinations** of amino acids with same mass of the original peptide.

9.2 Branch-and-Bound Algorithms

Say this was the spectrum given:

0	97	97	99	101	103	196	198	198	200	202	295	297	299	299	301	394	396	398	400	40

1. Find the amino acids whose weights lie in the spectrum.

G	A	S	P	V	T	C	I/L	N	D	K/Q	E	M	H	F	R	Y	W
57	71	87	97	99	101	103	113	114	115	128	129	131	137	147	156	163	186

(Let's take the first 4 1-mers)

P
V
T
C

1. Now make all 2-mers out of these 4 1-mers. Basically add all 18 amino acids to each 1-mer

PG	PA	PS	PP	PV	PT	PC	PI/PL	PN	PD	PK/PQ	PE	PM	PH	PF	PR	PY	PW
VG	VA	VS	VP	VV	VT	VC	VI/VL	VN	VD	VK/VQ	VE	VM	VH	VF	VR	VY	VW
TG	TA	TS	TP	TV	TT	TC	TI/TL	TN	TD	TK/TQ	TE	TM	TH	TF	TR	TY	TW
CG	CA	CS	CP	CV	CC	CC	CI/CL	CN	CD	CK/CQ	CE	CM	CH	CF	CR	CY	CW

1. In each of these 2-mers, find which lie in the given spectrum

PG	PA	PS	PP	**PV**	**PT**	**PC**	PI/PL	PN	PD	PK/PQ	PE	PM	PH	PF	PR	PY	PW
VG	VA	VS	VP	VV	VT	VC	VI/VL	VN	VD	VK/VQ	VE	VM	VH	VF	VR	VY	VW
TG	TA	TS	TP	TV	TT	TC	TI/TL	TN	TD	TK/TQ	TE	TM	TH	TF	TR	TY	TW
CG	CA	CS	CP	CV	CC	CC	CI/CL	CN	CD	CK/CQ	CE	CM	CH	CF	CR	CY	CW

And now we have:

PV
PT
PC

1. Now make all 3-mers out of these 3 2-mers. Basically add all 18 amino acids to each 2-mer

PVG	PVA	PVS	PVP	PVV	PVT	PVC	PVI/PVL	PVN	PVD	PVK/PVQ	PVE	PVM	PVH
PTG	PTA	PTS	PTP	PTV	PTT	PTC	PTI/PTL	PTN	PTD	PTK/PTQ	PTE	PTM	PTH
PCG	PCA	PCS	PCP	PCV	PCT	PCC	PCI/PCL	PCN	PCD	PCK/PCQ	PCE	PCM	PCH

1. In each of these 3-mers, find which lie in the given spectrum

PVG	PVA	PVS	PVP	**PVV**	PVT	PVC	PVI/PVL	PVN	PVD	PVK/PVQ	PVE	PVM	PVH
PTG	PTA	PTS	PTP	PTV	PTT	PTC	PTI/PTL	PTN	PTD	PTK/PTQ	PTE	PTM	PTH
PCG	PCA	PCS	PCP	PCV	PCT	PCC	PCI/PCL	PCN	PCD	PCK/PCQ	PCE	PCM	PCH

9.3 Leaderboard Cyclopeptide Sequencing

(work in progress)

10 Sequence Alignment

10.1 Why Align Sequences?

- You can establish the following relationships:
  1. Functional Relationship
  2. Structural Relationship
  3. Evolutionary Relationship

10.2 Types of Alignment

10.2.1 Global Alignment

1. What it is
   - Align all letters from query and target
   - Sequence must be closely related/similar
   - Example: **Needleman-Wunsch**
2. How it works
   (a) Initialization
   - Say we have two sequences $ATGCT$ and $AGCT$
   - Among these two sequences, if the lengths of the sequences are m and n, then make a matrix of size $(m+1)\mathbf{x}(n+1)$

		A	**T**	**G**	**C**	**T**
A						
G						
C						
T						

   (b) Matrix Filling
   Fill the matrix such that

- 1 = Match (added to diagonal element only)
- -1 = Mismatch (added to diagonal element only)
- -2 = Gap

		A	**T**	**G**	**C**	**T**
	0	-2	-4	-6	-8	-10
A	-2					
G	-4					
C	-6					
T	-8					

- For top/left element you add -2, and for the immediate top-left diagonal element, you add +-1 depending on if it's a match or not
- The final value of the element, would the maximum of whatever you find

		A	T	G	C	T
	0	-2	-4	-6	-8	-10
A	-2	1	-1	-3	-5	-7
G	-4	-1	0	0	-2	-4
C	-6	-3	-2	-1	1	-1
T	-8	-5	-2	-3	-1	2

(c) Trackback
You basically move from the bottom-right corner to the top-left corner. You can do this in 3 ways, and 'moving' means swapping the numbers

-

3. Another example, where penalties are different

- 1 = Match (added to diagonal element only)
- -1 = Mismatch (added to diagonal element only)
- -1 = Gap

		C	G	T	G	A	A	T	T	C	A	T
	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22
G	-2											
A	-4											
C	-6											
T	-8											
T	-10											
A	-12											
C	-14											

4. Code in biopython

```
from Bio import pairwise2

# Given DNA sequences
seq1 = "ATGCTAGC"
seq2 = "ATGCTAGCTAGC"
```

```
# Scoring parameters
match = 1
mismatch = -1
gap_open = -2
gap_extend = -2

# Perform global alignment
alignments = pairwise2.align.globalms(seq1, seq2, match, mismatch, gap_open, gap_extend)

# Print best alignment and score
print(pairwise2.format_alignment(*alignments[0]))
```

(a) `from Bio import pairwise2`
(b) `pairwise2.align.globalms()`
(c) `pairwise2.format_alignment(*alignments[0])`

10.2.2 Local Alignment

- Align only the regions with higher similarity i.e. you align only substrings
- This is suitable for more divergent sequences
- Example: **Smith-Waterman**

1. What is is
2. How it works
   (a) Initialization

		A	T	G	C	T
	0	0	0	0	0	0
A	0					
G	0					
C	0					
T	0					

   (b) Matrix filling

- Fill the matrix such that
  - 1 = Match (added to diagonal element only)
  - -1 = Mismatch (added to diagonal element only)
  - -2 = Gap
- But the catch is that if you get a negative value, you make it zero. That's why the initialization is all zeroes. (It was -2, -4, etc. . . , but negative values are truncated to 0)

		A	T	G	C	T
	0	0	0	0	0	0
A	0	1	0	0	0	0
G	0	0	0	1	0	0
C	0	0	0	0	2	0
T	0	0	1	0	0	3

(a) Traceback

		A	T	G	C	T
	0	0	0	0	0	0
A	0	1	0	0	0	0
G	0	0	0	1	0	0
C	0	0	0	0	2	0
T	0	0	1	0	0	3

3. Another example

		G	A	A	T	T	C	A	T
	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	1	0	0
C	0	0	0	0	0	0	1	0	0
T	0	0	0	0	1	1	0	0	1
C	0	0	0	0	0	0	2	0	0
A	0	0	1	1	0	0	0	3	0
T	0	0	0	0	2	1	0	0	4
G	0	1	0	0	0	0	0	0	0

4. Code in biopython

```
from Bio import pairwise2

# Given DNA sequences
seq1 = "TGTGACTA"
seq2 = "CATGGTCA"

# Scoring parameters
match = 1
mismatch = -1
gap_open = -2
gap_extend = -2

# Perform local alignment (Smith-Waterman Algorithm)
alignments = pairwise2.align.localms(seq1, seq2, match, mismatch, gap_open, gap_extend)

# Print best local alignment and score
print(pairwise2.format_alignment(*alignments[0]))
```