

Introduction aux formats de fichiers et algorithmes utilisés dans le TP2

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```
In [1]: import gzip
        from itertools import islice
```

1 Formats de fichiers

1.1 FASTA

Le fichier FASTA contient des séquences identifiées et annotées brièvement par une description.

```
>ID DESCRIPTION
SEQUENCE
```

```
In [2]: with gzip.open('GCF_000002985.6_WBcel235_rna.fna.gz', 'rt') as f:
        print(f.readline())
        print(f.readline())
```

```
>NM_001025782.2 Caenorhabditis elegans Phosphatidylinositol 3-kinase catalytic subunit type 3
ATGCGAGTCTCCACGTCAGTCAACGGTGGTGTGGGATTGTTTCGGCCTGTACCCGTTACTGTGTAGCTGATCCTGAACT
```

```
In [3]: def read_fasta(path):
        with gzip.open(path, 'rt') as f:
            accession, description, seq = None, None, None
            for line in f:
                if line[0] == '>':
                    # yield current record
                    if accession is not None:
                        yield accession, description, seq

                    # start a new record
                    accession, description = line[1:].rstrip().split(maxsplit=1)
                    seq = ''
            else:
                seq += line.rstrip()
```

```
In [4]: next(read_fasta('GCF_000002985.6_WBcel235_rna.fna.gz'))
```

```
Out[4]: ('NM_001025782.2',
        'Caenorhabditis elegans Phosphatidylinositol 3-kinase catalytic subunit type 3 (vps-3)',
        'ATGCGAGTCTCCACGTCAGTCAACGGTGGTGGTGGGATTGTTTCGGCCTGTACCCGTTACTGTGTAGCTGATCCTGAACTTCTT')
```

1.2 FASTQ

Le format FASTQ contient des fragments annotés avec une qualité pour chaque symboles lus par le système de séquençage.

```
@SEQID DESCRIPTION
SEQUENCE
+
QUALITY
```

```
In [5]: with gzip.open('reads.fastq.gz', 'rt') as f:
        print(f.readline())
        print(f.readline())
        print(f.readline())
        print(f.readline())
```

```
@VOGKRUTI 1:11:1
```

```
ACTCGATTTACTTGTACTGGAACGAGTTGCCAGTTGAGAGCGCATTCCCAGTGAGAGCCCGATCGTCTGCCGAAGACTTGCCGACAACTTCTCG
```

```
+
```

```
~~~~~
```

```
In [6]: def read_fastq(path):
        with gzip.open(path, 'rt') as f:
            for line in f:
                seqid, description = line[1:].rstrip().split(maxsplit=1)
                sequence = f.readline().rstrip()
                _ = f.readline()
                quality = f.readline().rstrip()
                yield seqid, description, sequence, quality
```

```
In [7]: next(read_fastq('reads.fastq.gz'))
```

```
Out[7]: ('VOGKRUTI',
        '1:11:1',
        'ACTCGATTTACTTGTACTGGAACGAGTTGCCAGTTGAGAGCGCATTCCCAGTGAGAGCCCGATCGTCTGCCGAAGACTTGCCGA',
        '~~~~~')
```

```
In [8]: %%time
        for _ in read_fastq('reads.fastq.gz'):
            pass
```

```
CPU times: user 1.82 s, sys: 16.9 ms, total: 1.84 s
Wall time: 1.85 s
```

1.3 BED

Le format BED est un format tabulaire de 3 à 12 colonnes qui contient des annotations de sous-séquences.

```
reference      start      end      name
```

Dans ce TP, nous utiliserons seulement les 4 premières colonnes pour identifier la référence, une paire de coordonnées (début, fin) et l'identifiant du contig assemblé depuis notre graphe de Bruijn.

```
In [9]: def read_bed(path):
        with open(path) as f:
            ref, start, end, name = f.readline().rstrip().split('\t')
            yield ref, int(start) - 1, int(end), name
```

```
In [10]: next(read_bed('example.bed'))
```

```
Out[10]: ('NM_001025782.2', 1760, 1860, 'GBYXDORA')
```

2 Notions de base et algorithmes

```
In [11]: seq = next(read_fasta('GCF_000002985.6_WBcel235_rna.fna.gz'))[2]
        l = len(seq)
        seq[:30]
```

```
Out[11]: 'ATGCGAGTCTCCACGTCAGTCAACGGTGGT'
```

3 k -mer

Sous-séquence de longueur k . Une chaîne de longueur l possède $l - k + 1$ k -mers.

```
In [12]: k = 21
        kmers = [seq[i:i+k] for i in range(l - k + 1)]
```

```
In [13]: for i, km in enumerate(kmers[:10]):
        print((i * ' ') + km)
```

```
ATGCGAGTCTCCACGTCAGTC
TGCGAGTCTCCACGTCAGTCA
GCGAGTCTCCACGTCAGTCAA
CGAGTCTCCACGTCAGTCAAC
GAGTCTCCACGTCAGTCAACG
AGTCTCCACGTCAGTCAACGG
```

```

GTCTCCACGTCAGTCAACGGT
TCTCCACGTCAGTCAACGGTG
CTCCACGTCAGTCAACGGTGG
TCCACGTCAGTCAACGGTGGT

```

4 Graphe de Brujin

Les sommets sont les k -mers et les arcs sont les transition sur un symbole de l'alphabet.

```
In [14]: seq[:10+k]
```

```
Out [14]: 'ATGCGAGTCTCCACGTCAGTCAACGGTGGTG'
```

```

In [15]: k = 7
         kmers = [seq[i:i+k] for i in range(1 - k + 1)]

         def edges(kmers_graph):
             for k in kmers_graph:
                 for s in 'ATCG':
                     successor = k[1:] + s
                     if successor in kmers_graph:
                         yield k, successor

         for v1, v2 in islice(edges(set(kmers[:10])), 10):
             print(v1, v2, 'transition on {}'.format(v2[-1]))

```

```

GTCTCCA TCTCCAC transition on C
AGTCTCC GTCTCCA transition on A
ATGCGAG TCGGAGT transition on T
CGAGTCT GAGTCTC transition on C
GAGTCTC AGTCTCC transition on C
TCTCCAC CTCCACG transition on G
GCGAGTC CGAGTCT transition on T
CTCCACG TCCACGT transition on T
TCGCGAGT GCGAGTC transition on C

```

```

In [16]: import networkx as nx
         %matplotlib inline
         import matplotlib.pyplot as plt

         k = 5
         kmers = [seq[i:i+k] for i in range(1 - k + 1)]

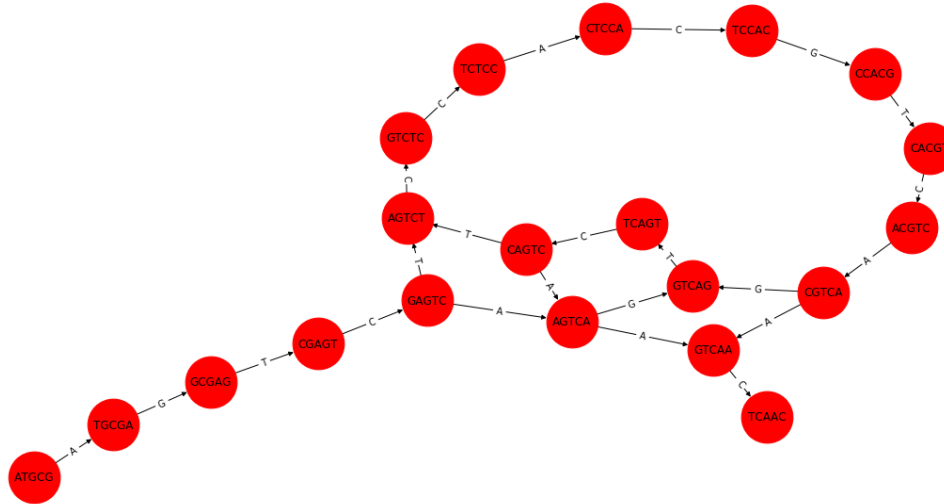
         plt.figure(figsize=(16,8))
         g = nx.DiGraph()
         g.add_nodes_from(set(kmers[:20]))

```

```

g.add_edges_from((u, v, {'label': v[-1]}) for u, v in edges(set(kmers[:20])))
nx.draw(g, pos=nx.drawing.nx_agraph.graphviz_layout(g), with_labels=True, node_size=300)
nx.draw_networkx_edge_labels(g, pos=nx.drawing.nx_agraph.graphviz_layout(g), edge_labels={e[2]: e[2]['label'] for e in g.edges()})
plt.show()

```



5 *k*-mer walk

Lorsque vous traverserez votre graphe, vous devrez adapter cette technique puisqu'il pourra exister plusieurs candidats potentiels et il sera également possible de revenir sur ses pas (i.e. une boucle).

```

In [17]: def kmer_walk(kmer_graph, start):
    k = start

    # yield the starting node
    yield k

    while True:
        for symbol in ['A', 'T', 'C', 'G']:
            candidate = k[1:] + symbol
            if candidate in kmer_graph:
                k = candidate
                yield k
                break
        else:
            break # break the while-loop if no more candidate is found

```

```

In [18]: k = 21
    kmers = [seq[i:i+k] for i in range(1 - k + 1)]

```

```

kmer_graph = set(kmers)
contig = None

for k in islice(kmer_walk(kmer_graph, start='GATGCATTAGAATTACTTTCA'), 20):
    if contig is None:
        contig = k
    else:
        contig += k[-1]
    print(((len(contig) - len(k)) * ' ') + k)
print(contig)

GATGCATTAGAATTACTTTCA
ATGCATTAGAATTACTTTCAA
TGCATTAGAATTACTTTCAAG
GCATTAGAATTACTTTCAAGT
CATTAGAATTACTTTCAAGTG
ATTAGAATTACTTTCAAGTGC
TTAGAATTACTTTCAAGTGCA
TAGAATTACTTTCAAGTG CAT
AGAATTACTTTCAAGTG CATT
GAATTACTTTCAAGTG CATT C
AATTACTTTCAAGTG CATT CA
ATTACTTTCAAGTG CATT CAC
TTACTTTCAAGTG CATT CACT
TACTTTCAAGTG CATT CACT C
ACTTTCAAGTG CATT CACT CA
CTTTCAAGTG CATT CACT CAT
TTTCAAGTG CATT CACT CAT C
TTCAAGTG CATT CACT CAT CC
TCAAGTG CATT CACT CAT CCG
CAAGTG CATT CACT CAT CCGG
GATGCATTAGAATTACTTTCAAGTG CATT CACT CAT CCGG

In [19]: print(seq[seq.find(contig)-10:seq.find(contig)+110])
print(10 * ' ' + contig)

TGAAGCTGAAGATGCATTAGAATTACTTTCAAGTG CATT CACT CAT CCGG CAGTTCGTGCATATTCTGTATCCCGTCTTCTAGAAGCTGCTTCT
GATGCATTAGAATTACTTTCAAGTG CATT CACT CAT CCGG

```

6 Exemple de cycle

La solution générale pour un cycle est de mémoriser les endroits déjà visité du graphe et d'interrompre le parcours.

```

In [20]: k = 6
kmers = [seq[i:i+k] for i in range(1 - k + 1)]

```

```

contig = None
closed = set()

for k in islice(kmer_walk(kmers, start='GATGCA'), 40):
    if contig is None:
        contig = k
    else:
        contig += k[-1]

    print(((len(contig) - len(k)) * ' ') + k, 'already visited!' if k in closed else

    if k in closed:
        break # stop traversal on repeat
    else:
        closed.add(k)

print(contig)

```

GATGCA
ATGCAA
TGCAAA
GCAAAA
CAAAAA
AAAAAT
AAAATA
AAATAT
AATATA
ATATAC
TATACA
ATACAA
TACAAA
ACAAAA
CAAAAA already visited!
GATGCAAAAAATATACAAAAA

7 Produire des identifiants aléatoires

```

In [21]: # Identifiant aléatoire
import random
import string
random.seed(123) # recommandé pour des résultats reproductibles!
''.join(random.choices(string.ascii_uppercase, k=10))

Out[21]: 'BCKCXANIWE'

```