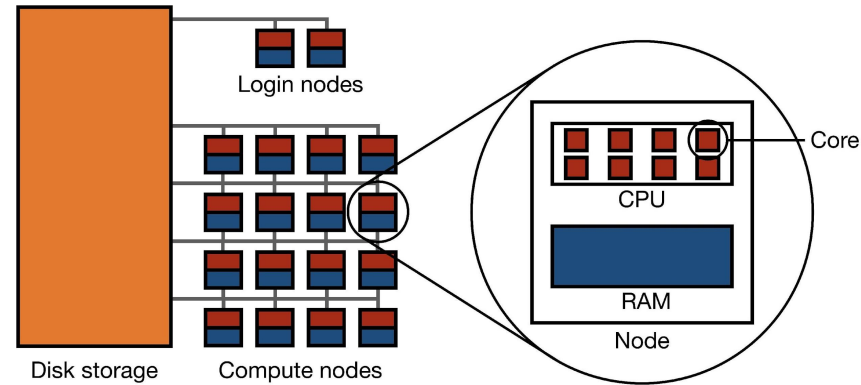


HPC environments and SLURM

- Questions 11-12

HPC environments

- Aggregated computing resources to gain performance greater than that of a single workstation, server, or computer
- Used to run computationally heavy processes
- Commonly used simultaneously by multiple users
- Job schedulers (i.e. SLURM) manage jobs sent by all users to ensure a safe and efficient use of the resources
- Extra configuration required:
 - RAM usage, CPUs, run time, ...



■ Disk ■ Compute ■ Memory ■ Network

Statistical Computing and Communication

<https://ekatsevi.github.io/statistical-computing/hpc-basics.html>

Local versus remote execution

Local

```
python myscript.py
```

Remote

```
sbatch \  
  --mem=100G \  
  --cpus-per-task=4 \  
  --time=00:00:30 \  
  --partition=partition_name \  
  python myscript.py
```

Local versus remote execution

Local

```
python myscript.py
```

Remote

```
jobscript.sh
```

```
#!/bin/bash  
#SBATCH --mem=100G  
#SBATCH --cpus-per-task=4  
#SBATCH --time=00:00:30  
#SBATCH --partition=partition_name
```



```
python myscript.py
```

```
sbatch jobscript.sh
```

Running Snakemake in HPC environments

- Snakemake can interact with multiple schedulers to run on clusters and cloud:
 - **AWS**
 - Azure
 - Flux
 - Google Batch
 - HTCondor
 - Kubernetes
 - **LSF**
 - **Slurm**
- Almost no changes required to the rules
 - Scheduler command can take job information from rule definition
 - One key parameter: maximum number of jobs running in parallel: `-j / --jobs`
- Implemented with:
 - v7 and before: `--cluster "<scheduler_name>"` in the Snakemake command
 - v8+: install plugins then `--executor "<scheduler_name>"` in the Snakemake command

Towards HPC execution

- Checking rule resource requirements  Benchmark directive
- Resource optimisation  Resources directive

Towards HPC execution

- Checking rule resource requirements → Benchmark directive
- Resource optimisation → Resources directive

Checking rule resource requirements: benchmarks

- 'benchmark' is a **directive**; its value is a path to a benchmark results file for a **rule**

```
rule rename_file:
    input:
        'data/test.txt'
    output:
        'results/renamed_file.txt'
    benchmark:
        'benchmarks/renaming.txt'
    shell:
        'mv {input} {output}'
```

Checking rule resource requirements: benchmarks

- 'benchmark' is a **directive**; its value is a path to a benchmark results file for a **rule**
- Snakemake will measure **runtime** and **memory usage** for the **rule** and save it to the file

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Checking rule resource requirements: benchmarks

- 'benchmark' is a **directive**; its value is a path to a benchmark results file for a **rule**
- Snakemake will measure **runtime** and **memory usage** for the **rule** and save it to the file
- Benchmark files must have the **same wildcards** as the **output**!
- Best practice: put all benchmarks in same folder

```
rule rename_file:
    input:
        'data/test.txt'
    output:
        'results/renamed_file.txt'
    benchmark:
        'benchmarks/renaming.txt'
    shell:
        'mv {input} {output}'
```

Towards HPC execution

- Checking rule resource requirements → Benchmark directive
- Resource optimisation → Resources directive

Optimising resource usage: memory and runtime

- 'resources' is a **directive**; its values set the resources available for a job
 - New kind of directive value: pair of <key>=<value>

Optimising resource usage: memory and runtime

- 'resources' is a **directive**; its values set the resources available for a job
 - New kind of directive value: pair of <key>=<value>
- **mem_<unit>**
 - Amount of memory needed by the job
 - <unit>: mb, gb, tb...
- **runtime_<unit>**
 - Amount of wall clock time a job needs to run
 - <unit>: s, m, h, d...

```
rule example:
    input:
        'data/test.txt'
    output:
        'results/modified_test.txt'
    resources:
        mem_gb = 1,
        runtime_h = 1
    shell:
        'command {input} > {output}'
```

Specifying job resources in Snakemake

- Job resources are determined as follows:
 - Specifying them by using the **resources** directive
 - Using default values when no resources specified:
 - RAM: $\max(2 \cdot \text{input.size_mb}, 1000)$
 - Disk space: $\max(2 \cdot \text{input.size_mb}, 1000)$
 - Temporary directory: system's tempdir
- Default resources can also be extended when calling Snakemake (i.e. slurm account)

```
rule myrule:
    input:
        'input_{file}.txt'
    output:
        'output_{file}.txt'
    resources:
        mem_mb = 100
    shell:
        'cat {input} > {output}'
```

Rule-specific settings in the Snakefile

- Some jobs are so small that it would be wasteful (and would take longer) to execute on an HPC
- You can define local execution rules using:
 - **localrules** keyword

```
localrules: light

rule light:
    input: 'input.txt'
    output: 'light_output.txt'
    resources:
        mem_mb = 100
    shell:
        'bash light.sh -i {input} -o {output}'

rule heavy:
    input: light.output
    output: 'heavy_output.txt'
    resources:
        mem_mb = 40000
    shell:
        'bash heavy.sh -i {input} -o {output}'
```


Rule-specific settings in the Snakefile

- Some jobs are so small that it would be wasteful (and would take longer) to execute on an HPC
- You can define local execution rules using:
 - **localrules** keyword
 - **localrule** directive

```
rule light:
    input: 'input.txt'
    output: 'light_output.txt'
    resources:
        mem_mb = 100
    localrule: True
    shell:
        'bash light.sh -i {input} -o {output}'

rule heavy:
    input: light.output
    output: 'heavy_output.txt'
    resources:
        mem_mb = 40000
    shell:
        'bash heavy.sh -i {input} -o {output}'
```

Configuration profiles

Configuration profiles

- Preconfigured configuration parameters: resources, executor, sdm...
 - Can manage executor parameters as well:
 - Scripts to submit jobs
 - Scripts to check job status
 - Advanced customisation
- Currently, there are two types of profile:
 - Global: directory stored in `~/.config/snakemake/<profile_name>/`
 - Workflow-specific: directory named `<profile_name>` and containing a `config.yaml` file.
- The directory contains config files in YAML format.
- Official list of Snakemake profiles [here](#)

Configuration profiles

./
├─ input_data/
├─ Snakefile
├─ config.yaml
└─ myprofile/
 └─ **config.yaml**

```
executor: cluster-generic  
cluster-generic-submit-cmd: 'sbatch -job-name={rule} -cpus-per-task={threads}'  
jobs: 10
```

- **executor:** used to indicate how to communicate with the scheduler
 - **cluster-generic** is a Snakemake plugin that handles communication with the scheduler
- **cluster-generic-submit-cmd:** command to use to run the jobs
 - In SLURM, this command is **sbatch** followed by the arguments you want to use
- **jobs:** used to indicate the maximum amount of jobs to run simultaneously
 - Useful to avoid overloading the cluster

Running Snakemake using a profile

- Once set up, running Snakemake using a profile is as simple as:

```
snakemake --profile <path_to_profile_folder>
```

Exercises

- Through the day:
 - Develop a simple RNAseq analysis workflow, from reads (fastq files) to Differentially Expressed Genes (DEG)
- For this session:
 - Benchmark rules to understand resource usage
 - Optimise resource usage
 - Create a configuration profile
 - Run a Snakemake workflow while sending jobs through SLURM

Conclusion

- Snakemake helps with reproducibility:
 - OS, language, software, versions, parameters control via Conda and containers
 - Avoid installation problems!
 - Readability: written in Python, has a well-defined structure
 - Availability: easy to share via WorkflowHub, [Snakemake workflow catalog](#) or git
 - **Every command run by Snakemake is saved!**
- And it has many uses:
 - Easily deployable/executable, **locally** or **remotely**
 - Scalable, up to thousands of jobs
 - Easy to parallelise
 - Snakemake can do a lot for you!
 - Beautiful DAG in one command, no more powerpoint or Photoshop!

