Parallel Models

Different ways to exploit parallelism

Outline

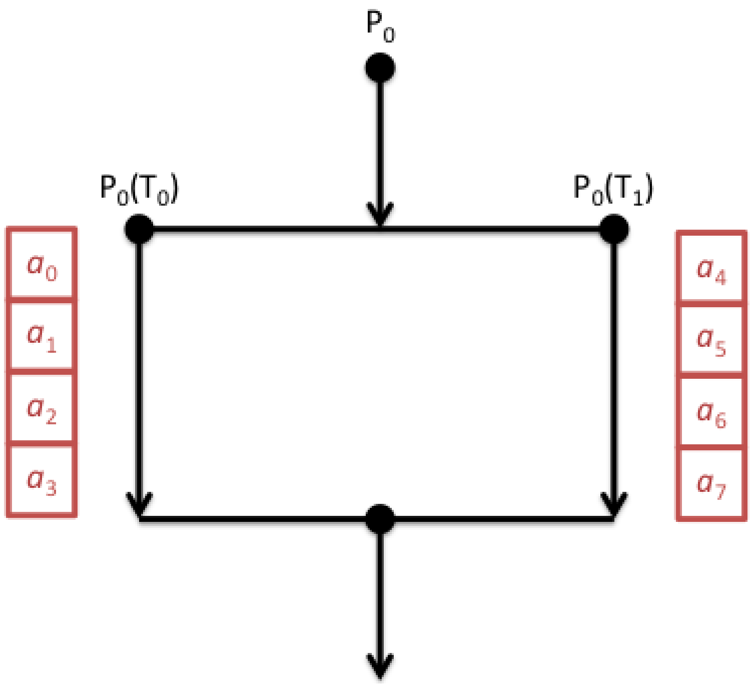
- Shared-Variables Parallelism
  - threads
  - shared-memory architectures
- Message-Passing Parallelism
  - processes
  - distributed-memory architectures
- Practicalities
  - compilers
  - libraries
  - usage on real HPC architectures

Shared Variables

Threads-based parallelism

Shared-memory concepts

- Have already covered basic concepts
  - threads can all see data of parent process
  - can run on different cores
  - potential for parallel speedup



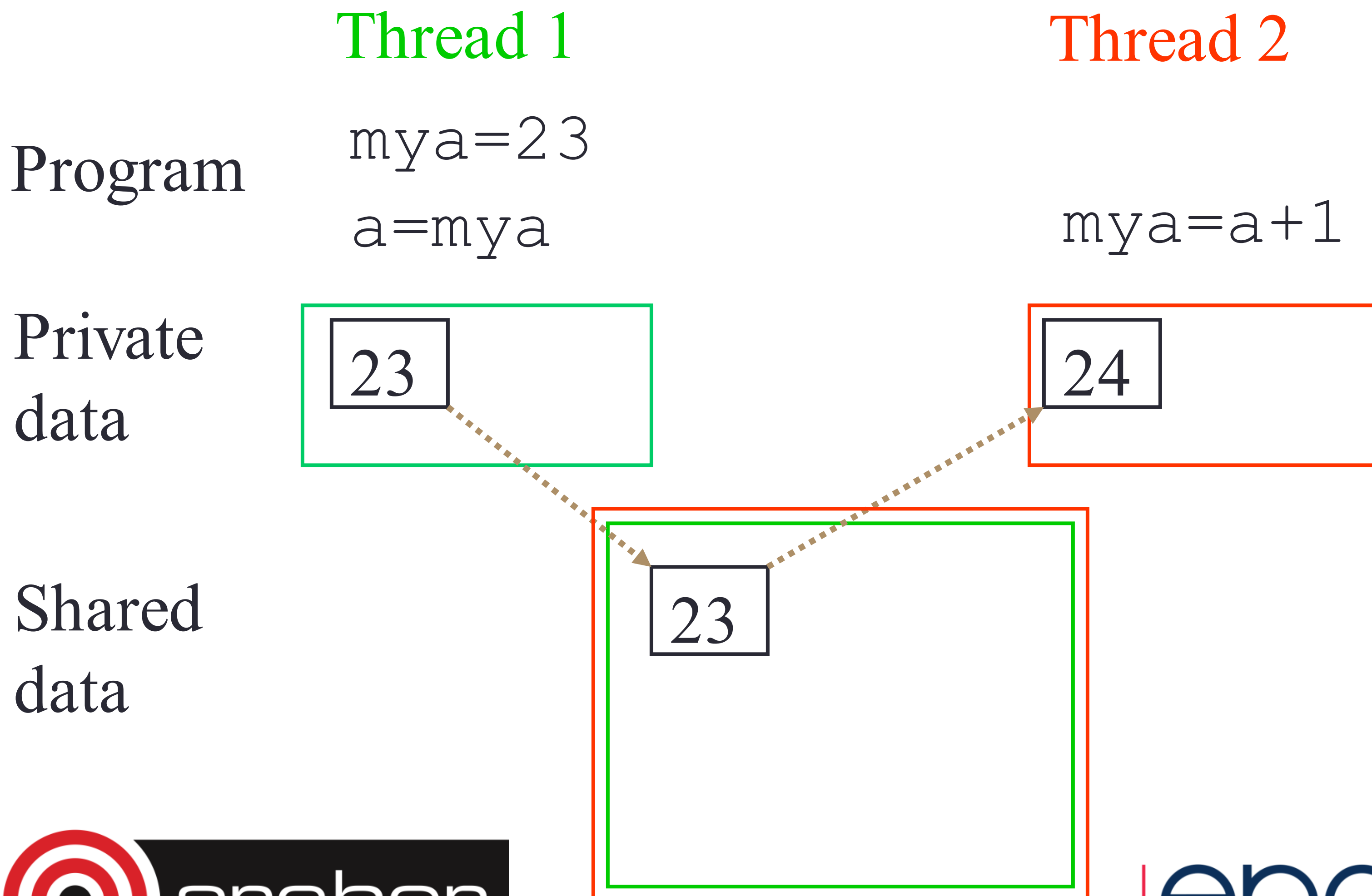
Analogy

- One very large whiteboard in a two-person office
  - the shared memory
- Two people working on the same problem
  - the threads running on different cores attached to the memory

- How do they collaborate?
  - working together
  - but not interfering

- Also need *private* data

Thread Communication

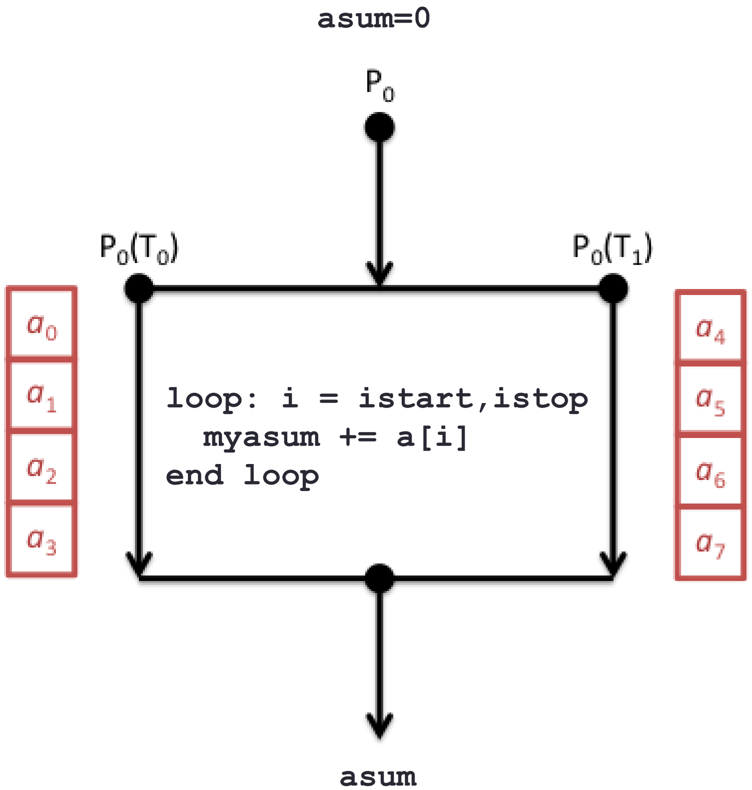


Synchronisation

- Synchronisation crucial for shared variables approach
  - thread 2's code must execute *after* thread 1
- Most commonly use global barrier synchronisation
  - other mechanisms such as locks also available
- Writing parallel codes relatively straightforward
  - access shared data as and when its needed
- Getting correct code can be difficult!

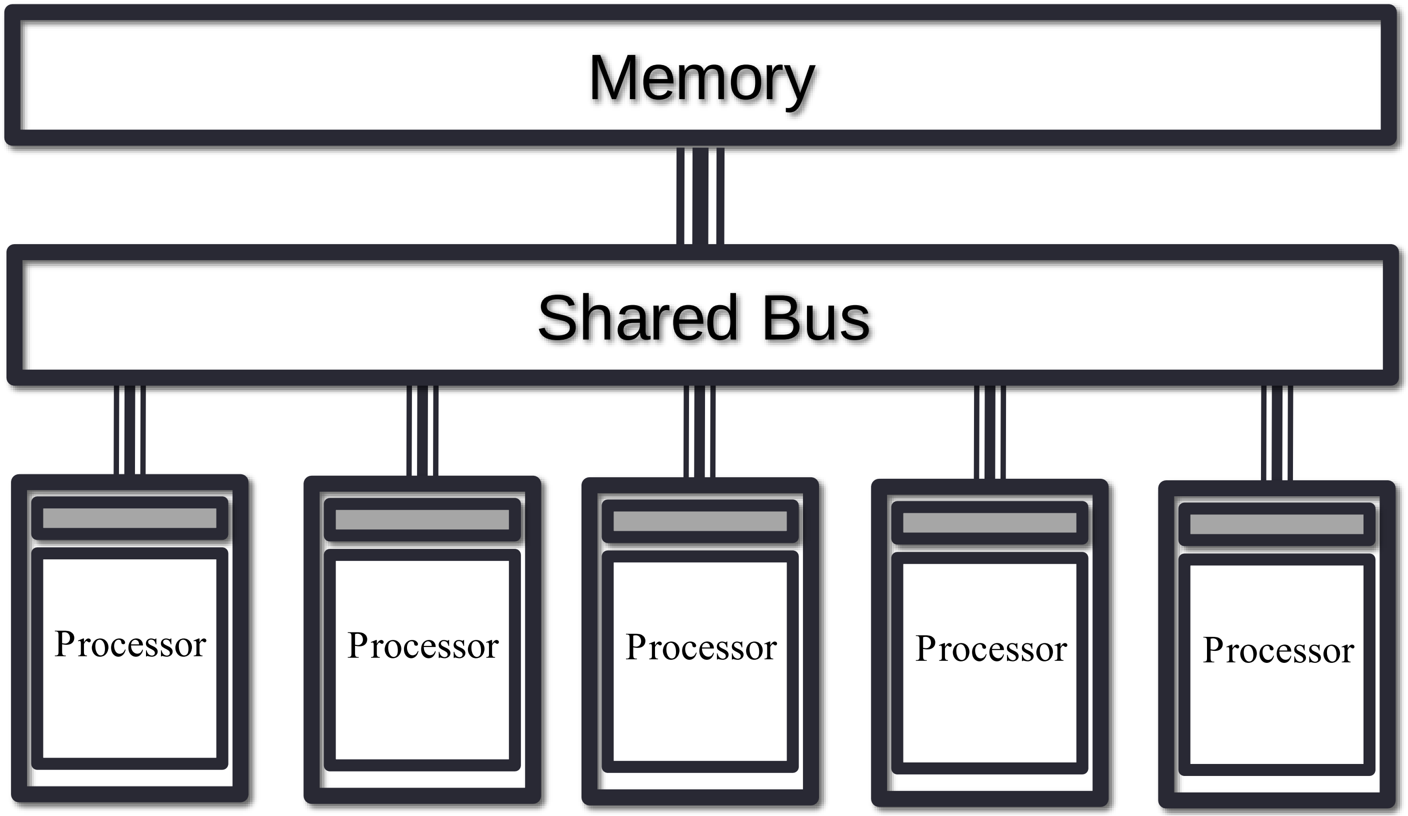
Specific example

- Computing **asum** $= a_0 + a_1 + \ldots a_7$
  - shared:
    - main array: **a[8]**
    - result: **asum**
  - private:
    - loop counter: **i**
    - loop limits: **istart, istop**
    - local sum: **myasum**
  - synchronisation:
    - thread0: **asum += myasum**
    - barrier
    - thread1: **asum += myasum**



Hardware

- Needs support of a shared-memory architecture



Threads: Summary

- Shared blackboard a good analogy for thread parallelism
- Requires a shared-memory architecture
  - in HPC terms, cannot scale beyond a single node

- Threads operate independently on the shared data
  - need to ensure they don't interfere; synchronisation is crucial

- Threading in HPC usually uses OpenMP directives
  - supports common parallel patterns
  - e.g. loop limits computed by the compiler
  - e.g. summing values across threads done automatically

Message Passing

Process-based parallelism

Analogy

- Two whiteboards in different single-person offices
  - the distributed memory
- Two people working on the same problem
  - the processes on different nodes attached to the interconnect
- How do they collaborate?
  - to work on single problem
- Explicit communication
  - e.g. by telephone
  - no shared data

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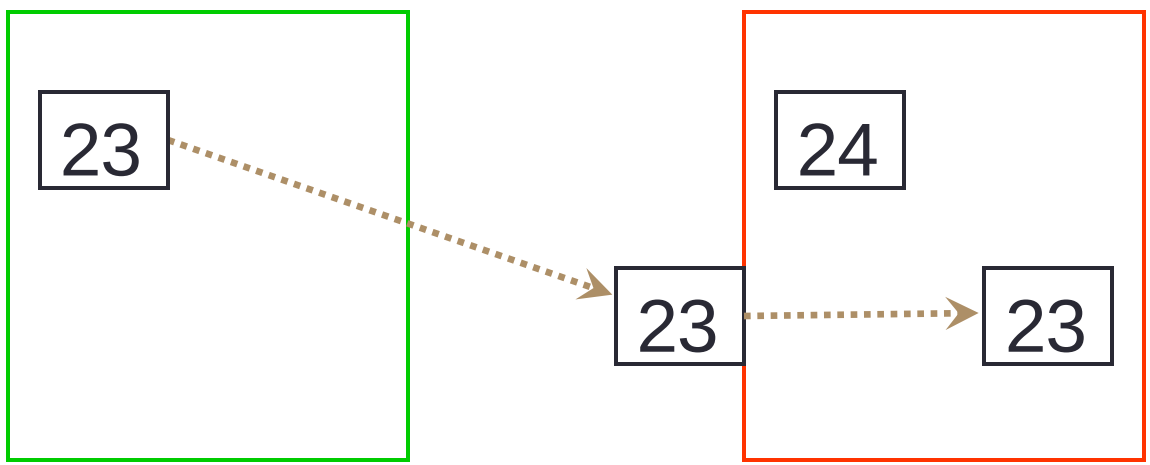
Process communication

	Process 1	Process 2
Program	`a=23` `Send(2,a)`	`Recv(1,b)` `a=b+1`

Data



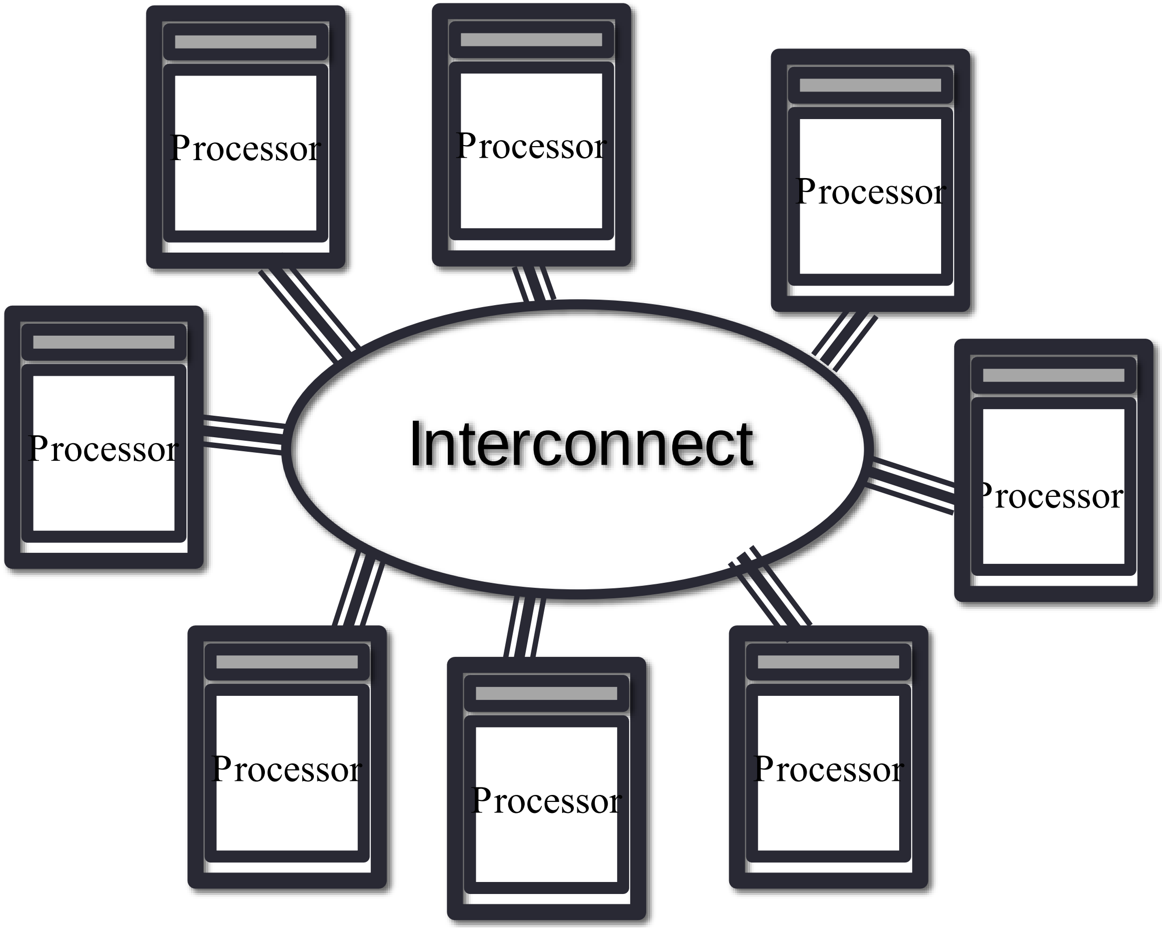
Synchronisation

- Synchronisation is automatic in message-passing
  - the messages do it for you

- Make a phone call …
  - … wait until the receiver picks up
- Receive a phone call
  - … wait until the phone rings

- No danger of corrupting someone else's data
  - no shared blackboard

Hardware

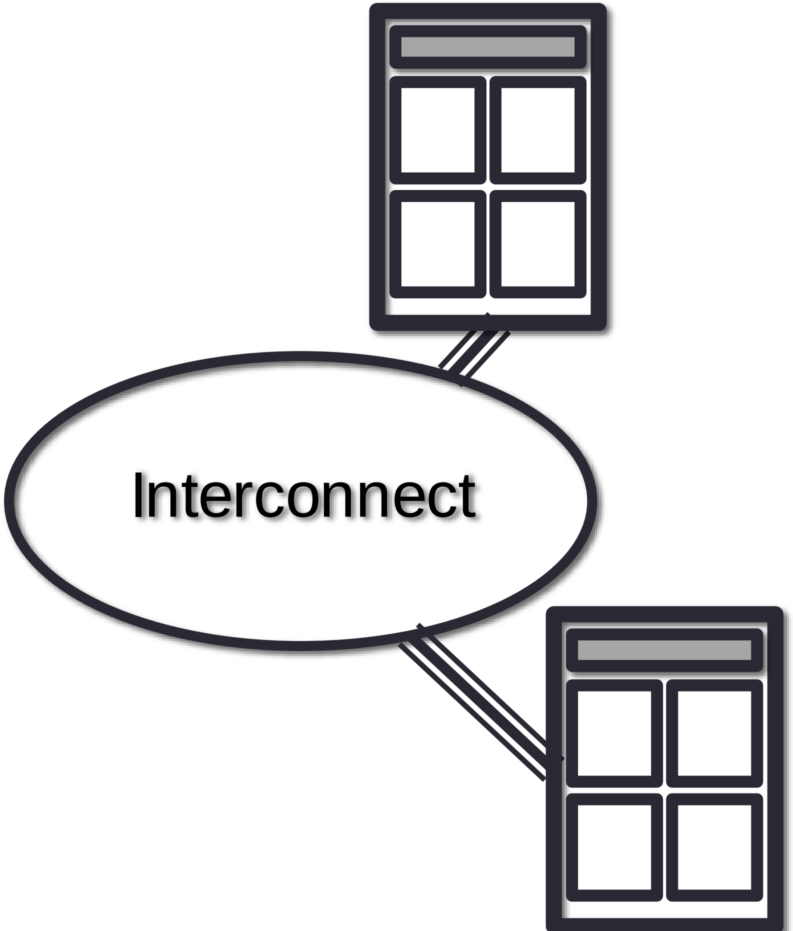


- Natural map to distributed-memory
  - one process per processor-core
  - messages go over the interconnect, between nodes/OS's

Processes: Summary

- Processes cannot share memory
  - ring-fenced from each other
  - analogous to white boards in separate offices
- Communication requires explicit *messages*
  - analogous to making a phone call, sending an email, …
  - synchronisation is done by the messages
- Almost exclusively use Message-Passing Interface
  - MPI is a library of function calls / subroutines

Practicalities

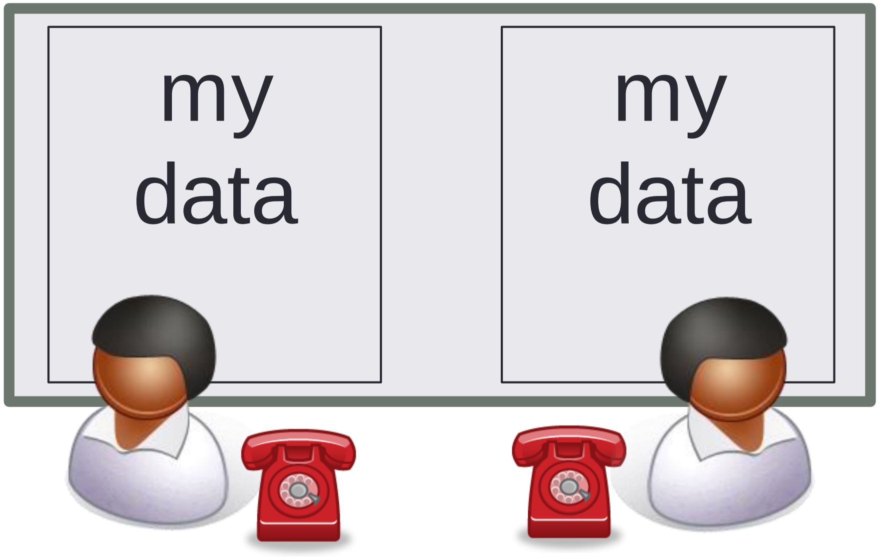


- 8-core machine might only have 2 nodes
  - how do we run MPI on a real HPC machine?
- Mostly ignore architecture
  - imagine we have single-core nodes
- Messages between processes on the same node are fast
  - but remember they also share access to the network

Message Passing on Shared Memory

- Run one process per core
  - don't directly exploit shared memory
  - analogy is phoning your office mate
  - actually works well in practice!

- Message-passing programs run by a special job launcher
  - user specifies #copies
  - some control over allocation to nodes



Summary

- Shared-variables parallelism
  - uses threads
  - requires shared-memory machine
  - easy to implement but limited scalability
  - in HPC, done using OpenMP compilers
- Distributed memory
  - uses processes
  - can run on any machine: messages can go over the interconnect
  - harder to implement but better scalability
  - on HPC, done using the MPI library