# Message Passing Programming

Modes, Tags and Communicators

# Reusing this material

# Overview

- Lecture will cover
  - explanation of MPI modes (**`Ssend`**, **`Bsend`** and **`Send`**)
  - meaning and use of message tags
  - rationale for MPI communicators

- These are all commonly misunderstood
  - essential for all programmers to understand modes
  - often useful to use tags
  - certain cases benefit from exploiting different communicators

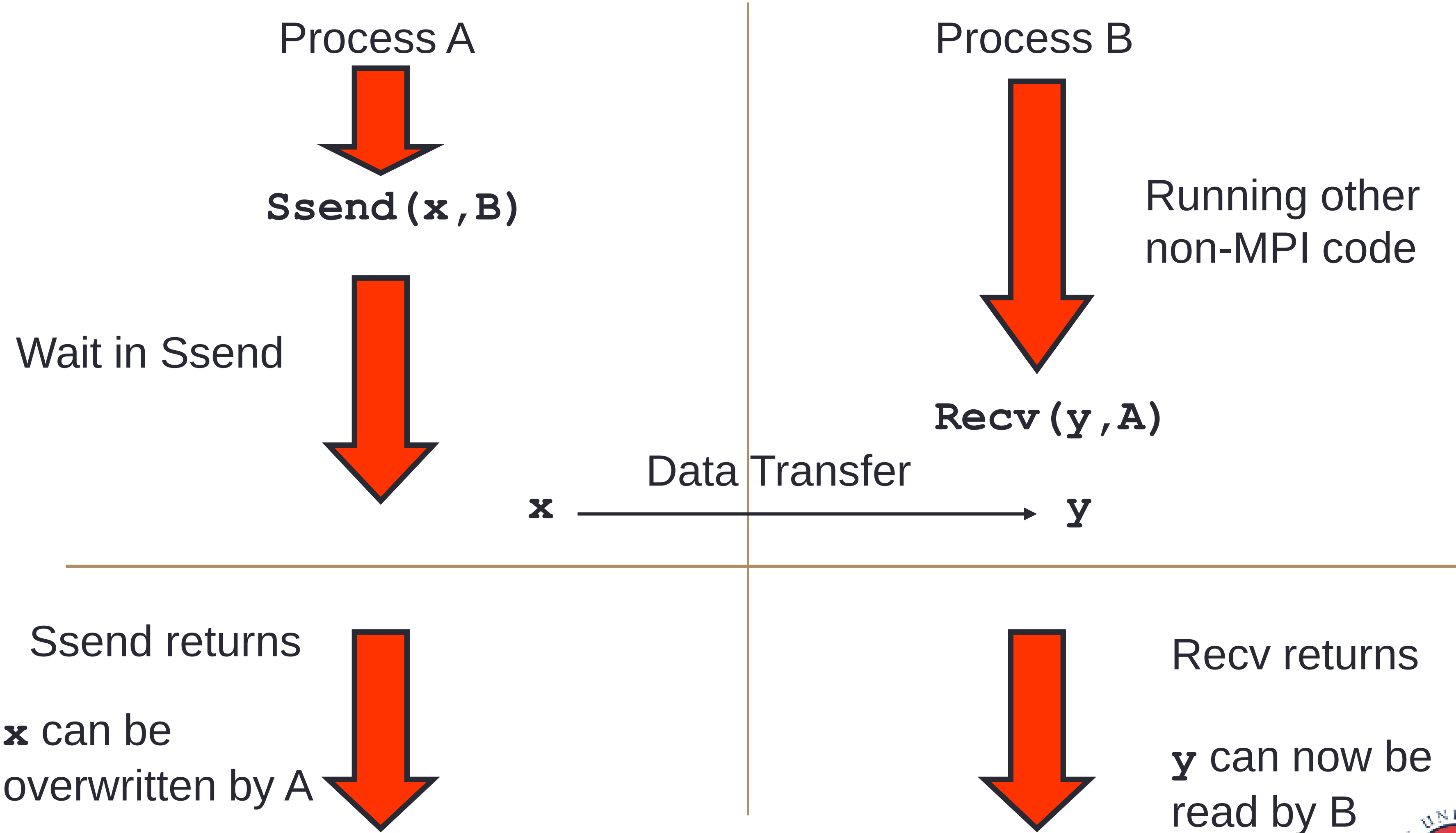
# Modes

- **`MPI_Ssend`** (Synchronous Send)
  - guaranteed to be synchronous
  - routine will not return until message has been delivered

- **`MPI_Bsend`** (Buffered Send)
  - guaranteed to be asynchronous
  - routine returns before the message is delivered
  - system copies data into a buffer and sends it later on

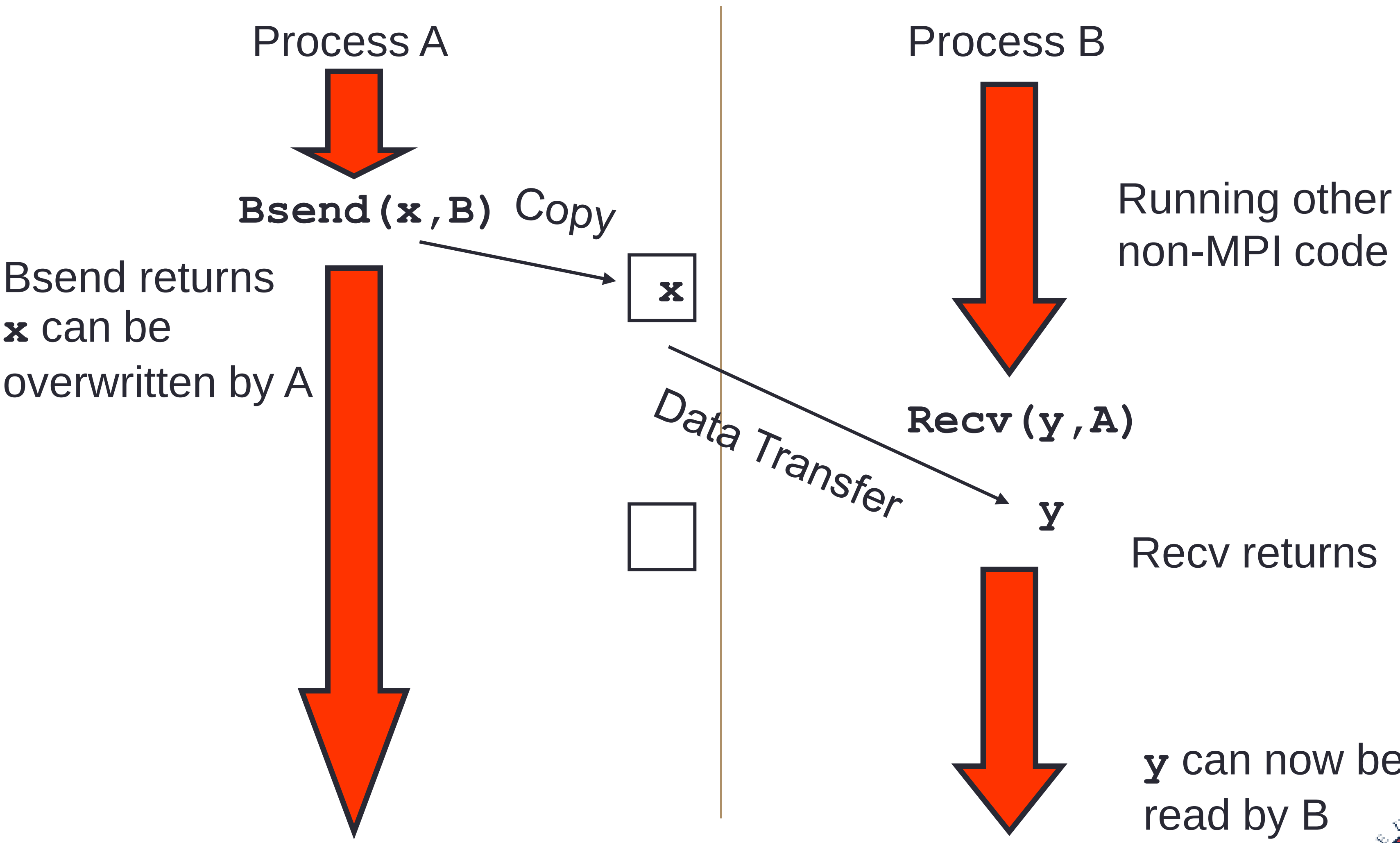
- **`MPI_Send`** (standard Send)
  - may be implemented as synchronous or asynchronous send
  - this causes a lot of confusion (see later)

# MPI_Ssend



Process A
Process B
Ssend(x,B)
Running other
non-MPI code
Wait in Ssend
Recv(y,A)
Data Transfer
x
y
Ssend returns
x can be
overwritten by A
Recv returns
y can now be
read by B

# MPI_Bsend



Process A
Process B
Bsend(x,B)
Copy
x
Running other
non-MPI code
Bsend returns
x can be
overwritten by A
Data Transfer
Recv(y,A)
y
Recv returns
y can now be
read by B

# Notes

- **`Recv`** is always synchronous
  - if process B issued **`Recv`** before the **`Bsend`** from process A, then B would wait in the **`Recv`** until **`Bsend`** was issued

- Where does the buffer space come from?
  - for **`Bsend`**, the user provides a single large block of memory
  - make this available to MPI using **`MPI_Buffer_attach`**

- If A issues another **`Bsend`** before the **`Recv`**
  - system tries to store message in free space in the buffer
  - if there is not enough space then **`Bsend`** will FAIL!

# Send

- Problems
  - **`Ssend`** runs the risk of deadlock
  - **`Bsend`** less likely to deadlock, and your code may run faster, but
    - the user must supply the buffer space
    - the routine will FAIL if  this buffering is exhausted
- **`MPI_Send`** tries to solve these problems
  - buffer space is provided by the system
  - **`Send`** will normally be asynchronous (like **`Bsend`**)
  - if buffer is full, **`Send`** becomes synchronous (like **`Ssend`**)
- **`MPI_Send`** routine is unlikely to fail
  - but could cause your program to deadlock if buffering runs out

# MPI_Send

| Process A | Process B |
| --- | --- |
| Send(x,B) | Send(y,A) |
| Recv(x,B) | Recv(y,A) |

- This code is NOT guaranteed to work
  - will deadlock if Send is synchronous
  - is guaranteed to deadlock if you use **`Ssend`**!

# Solutions

- To avoid deadlock
  - either match sends and receives explicitly
  - e.g. for ping-pong
    - process A sends then receives
    - process B receives then sends

- For a more general solution use non-blocking communications (see later)

- For this course you should program with **`Ssend`**
  - more likely to pick up bugs such as deadlock than **`Send`**

# Checking for Messages

- MPI allows you to check if any messages have arrived
  - you can "probe" for matching messages
  - same syntax as receive except no receive buffer specified

- e.g. in C:

```
int MPI_Probe(int source, int tag,
              MPI_Comm comm, MPI_Status *status)
```

- Status is set as if the receive took place
  - e.g. you can find out the size of the message and allocate space prior to receive

- Be careful with wildcards
  - you can use, e.g., `MPI_ANY_SOURCE` in call to probe
  - but must use **specific** source in receive to guarantee matching same message
  - e.g. `MPI_Recv(buff, count, datatype, status.MPI_SOURCE, ...)`

# Tags

- Every message can have a tag
  - this is a non-negative integer value
  - maximum value can be queried using **`MPI_TAG_UB`** attribute
  - MPI guarantees to support tags of at least 32767
  - not everyone uses them; many MPI programs set all tags to zero
- Tags can be useful in some situations
  - can choose to receive messages only of a given tag
- Most commonly used with **`MPI_ANY_TAG`**
  - receives the most recent message regardless of the tag
  - user then finds out the actual value by looking at the **`status`**

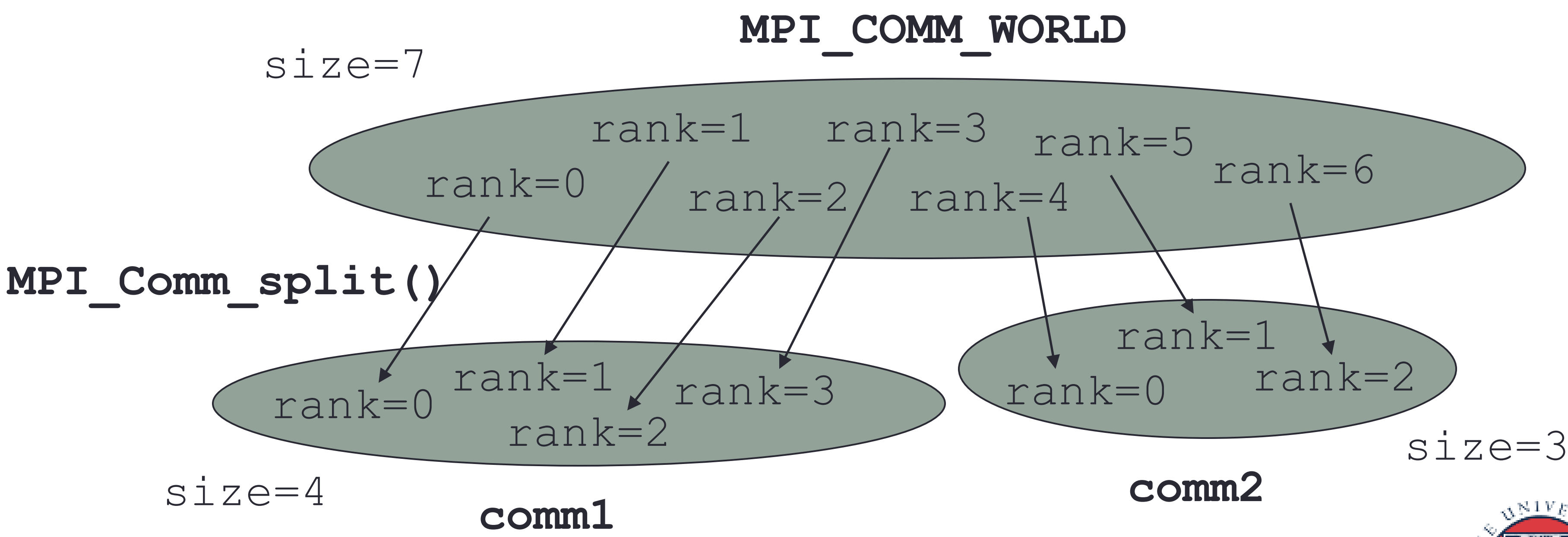
# Communicators

- All MPI communications take place within a communicator
  - a communicator is fundamentally a group of processes
  - there is a pre-defined communicator: **`MPI_COMM_WORLD`** which contains ALL the processes
    - also **`MPI_COMM_SELF`** which contains only one process

- A message can ONLY be received within the same communicator from which it was sent
  - unlike tags, it is not possible to wildcard on **`comm`**

# Uses of Communicators (i)

- Can split **`MPI_COMM_WORLD`** into pieces
  - each process has a new rank within each sub-communicator
  - guarantees messages from the different pieces do not interact
    - can attempt to do this using tags but there are no guarantees



# Uses of Communicators (ii)

- Can make a copy of **`MPI_COMM_WORLD`**
  - e.g. call the **`MPI_Comm_dup`** routine
  - containing all the same processes but in a new communicator

- Enables processes to communicate with each other safely within a piece of code
  - guaranteed that messages cannot be received by other code
  - this is **essential** for people writing parallel libraries (e.g. a Fast Fourier Transform) to stop library messages becoming mixed up with user messages
    - user cannot intercept the the library messages if the library keeps the identity of the new communicator a secret
    - not safe to simply try and reserve tag values due to wildcarding

# Summary (i)

- Question: Why bother with all these send modes?
- Answer
  - it is a little complicated, but you should make sure you understand
  - **`Ssend`** and **`Bsend`** are clear
    - map directly onto synchronous and asynchronous sends
  - **`Send`** can be either synchronous or asynchronous
    - MPI is trying to be helpful here, giving you the benefits of **`Bsend`** if there is sufficient system memory available, but not failing completely if buffer space runs out
    - in practice this leads to endless confusion!
- The amount of system buffer space is variable
  - programs that run on one machine may deadlock on another
  - you should **NEVER** assume that **`Send`** is asynchronous!

# Summary (ii)

- Question: What are the tags for?
- Answer
  - if you don’t need them don’t use them!
    - perfectly acceptable to set all tags to zero
  - can be useful for debugging
    - e.g. always tag messages with the rank of the sender

# Summary (iii)

- Question: Can I just use **`MPI_COMM_WORLD`**?
- Answer
  - yes: many people never need to create new communicators in their MPI programs
  - however, it is probably bad practice to specify **`MPI_COMM_WORLD`** explicitly in your routines
    - using a variable will allow for greater flexibility later on, e.g.:

```
MPI_Comm comm;          /* or INTEGER for Fortran */
comm = MPI_COMM_WORLD;
...
MPI_Comm_rank(comm, &rank);
MPI_Comm_size(comm, &size);
....
```

# Conclusion

- **`MPI_Send`** can be synchronous or asynchronous
  - allows MPI to choose the optimal method, but ...
    - varies depending on message size, number of MPI processes, library, ...
    - can cause incorrect codes (which deadlock if synchronous) to run OK
    - your code may run on your laptop or the login node but not on Cirrus compute nodes, or run on a single node but not multiple nodes, ...
- Solution
  - develop with synchronous send **`MPI_Ssend`** (or **`MPI_Issend`**)
    - ensures your code is correct
  - do production runs using **`MPI_Send`** (or **`MPI_Isend`**)
    - your code may be faster
  - a code that runs correctly with **`MPI_Ssend`** is extremely unlikely to be incorrect using **`MPI_Send`**