# Introduction to MPI

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# MPI (Message Passing Interface)?

- Standardized message passing library specification (IEEE)
  - for parallel computers, clusters and heterogeneous networks
  - not a specific product, compiler specification etc.
  - many implementations, MPICH, LAM, OpenMPI …
- Portable, with Fortran and C/C++ interfaces.
- Many functions
- Real parallel programming
- Notoriously difficult to debug

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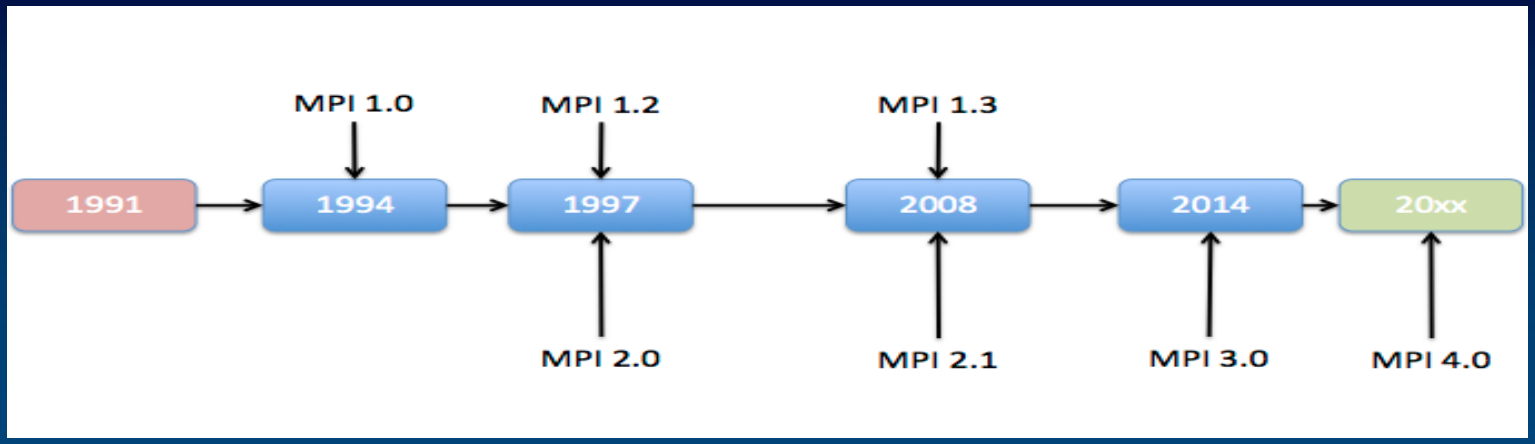
# Information about MPI




- **http://www.mpi-forum.org/docs/**
- **MPI: The Complete Reference**, Marc Snir and William Gropp et al, The MIT Press, 1998 (2-volume set)
- **Using MPI: Portable Parallel Programming With the Message-Passing Interface** and **Using MPI-2: Advanced Features of the Message-Passing Interface.** William Gropp, Ewing Lusk and Rajeev Thakur, MIT Press, 1999 – also available in a single volume *ISBN 026257134X.*
- **Parallel Programming with MPI**, Peter S. Pacheco, Morgen Kaufmann Publishers, 1997 - *very good introduction.*
- **https://computing.llnl.gov/tutorials/mpi/**

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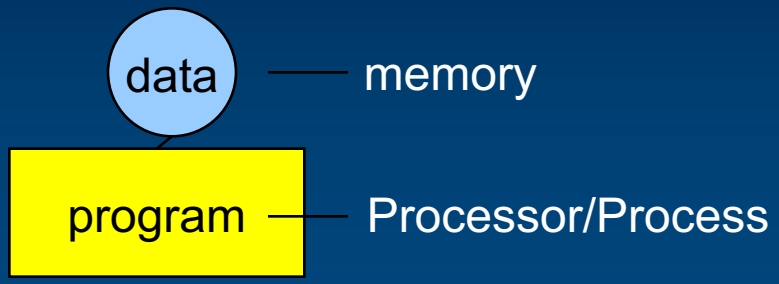
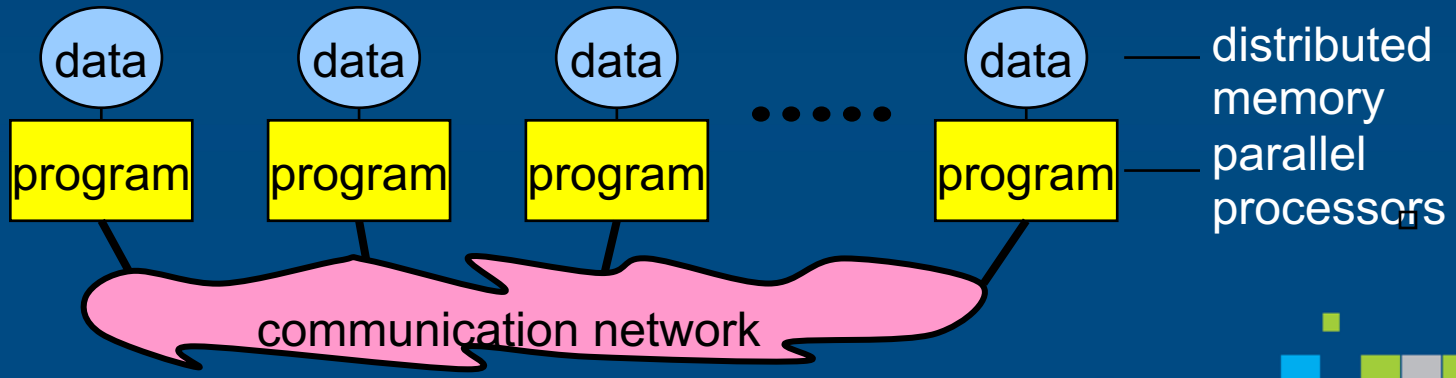
# The Message-Passing Programming Paradigm

- **Sequential Programming Paradigm**




A processor may
run many processes

- **Message Passing Programming Paradigm**



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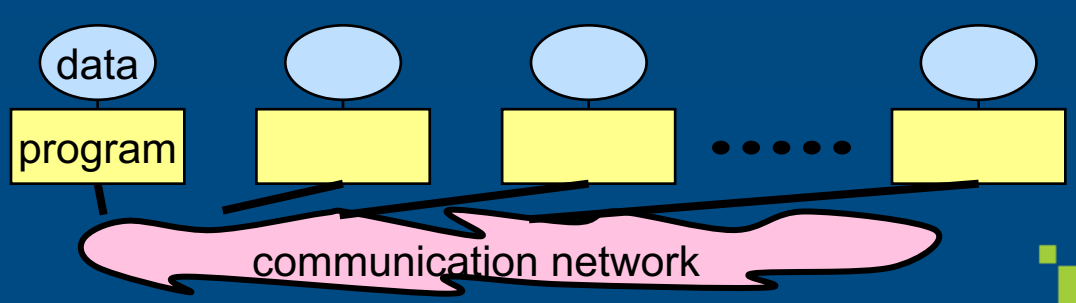
- A **process** is a program performing a task on a **processor/core**
- Each processor/process in a message passing program runs a instance/copy of a ***program:***
  - written in a conventional sequential language: C/C++, Fortran, python
  - typically a single program operating on multiple dataset
  - the variables of each sub-program have
    - the same name
    - but different locations (distributed memory) and different data!
    - i.e., all variables are local to a process
  - communicate via special send & receive routines (***message passing***)



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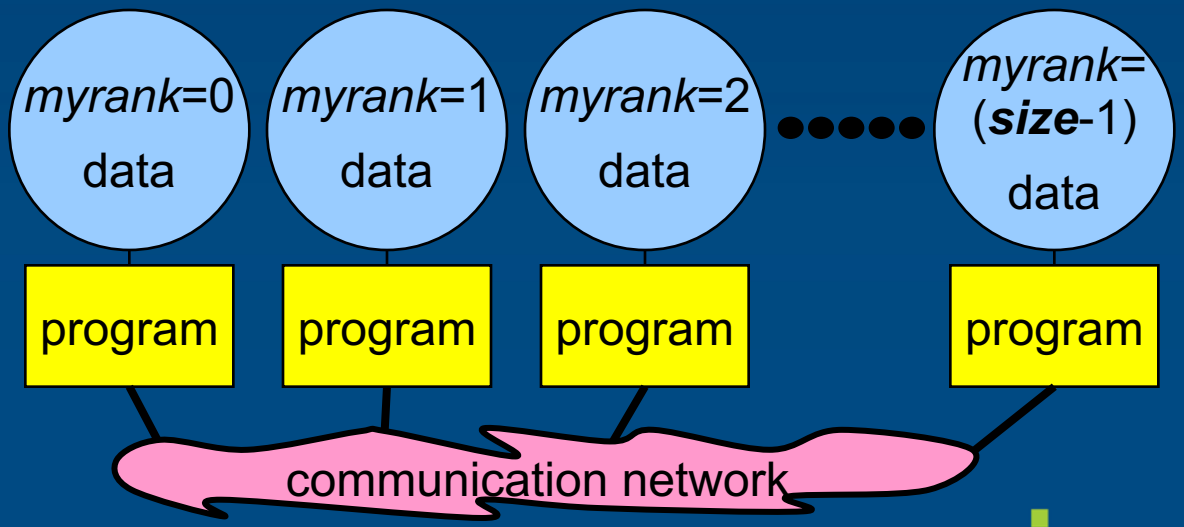
# Data and Work Distribution

- To communicate together mpi-processes need identifiers: **rank = identifying number**
- all distribution decisions are based on the ***rank***
  - i.e., which process works on which data



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# Example : sum of elements of a vector

- **Sequential code**

```
sum = 0
for (int i = 0; i < 1000 ;++i)
    sum = sum + array[i] ;
```

- **parallel code**

```
sum = 0
chunkSize = 1000 / numProc
for (int i= rank*chunkSize; i< (rank + 1)*chunkSize; ++i)
                sum = sum + array[i] ;

    if( rank != root)
      send (partialsum) to root
    else
      receive(partialsum) from workers
```

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# On each processor

```
sum = 0
for (int i= 0; i < 500; ++i)
    sum = sum + array[i] ;
```

$P_0$

```
sum = 0
for (int i = 500; i < 1000; ++i)
    sum = sum + array[i] ;
```

$P_1$

- The same program
- The same variables, but different values

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# What is SPMD

- **S**ingle **P**rogram, **M**ultiple **D**ata
- Same (sub-)program runs on each processor
- MPI allows also MPMD, i.e., **Multiple** Program, ...
  - but some vendors may be restricted to SPMD
  - MPMD can be emulated with SPMD

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# Emulation of MPMD

- C/C++:

```
main(int argc, char **argv) {
if (myrank < .... /* process should run the ocean model */){
      ocean( /* arguments */ );
   } else {
     weather( /* arguments */ );
   }
 }
```

- Fortran

```
program forecast
if (myrank < ... ) then   !! process should run the ocean model
        call  ocean ( some arguments )
ELSE
        call  weather ( some arguments )
endif
end program forecast
```

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# Message Passing System

- A sub-program needs to be connected to a message passing system
- A message passing system is similar to:
  - phone line
  - mail box
  - fax machine
  - etc.
- MPI:
  - program must be linked with an MPI library
  - program must be started with the MPI startup tool

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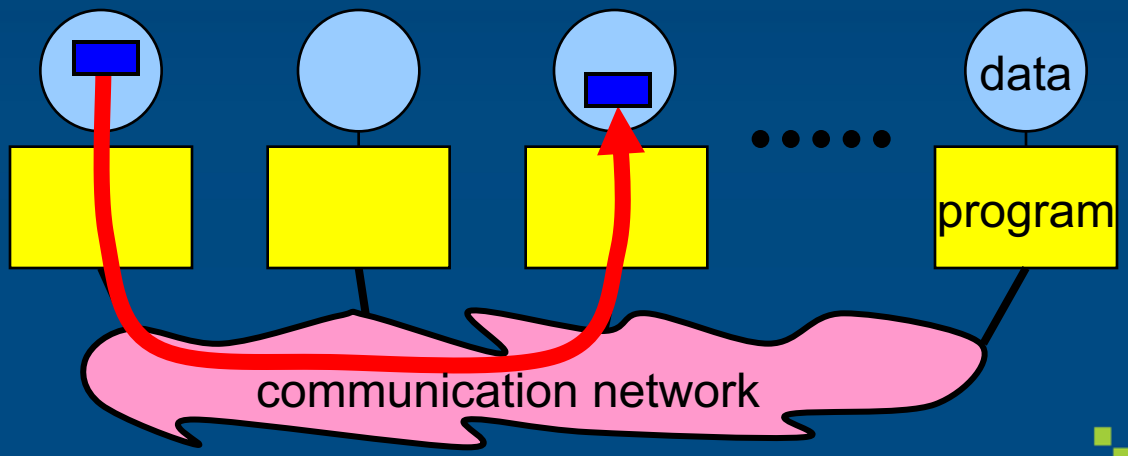
# Message passing

- Messages are packets of data moving between sub-programs
- Necessary information for the message passing system:
  - sending process – receiving process i.e., the ranks
  - source location – destination location
  - source data type – destination data type
  - source data size – destination buffer size



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# Point-to-Point Communication

- Simplest form of message passing.
- One process sends a message to another.
- Different types of point-to-point communication:
  - synchronous send
  - buffered = asynchronous send

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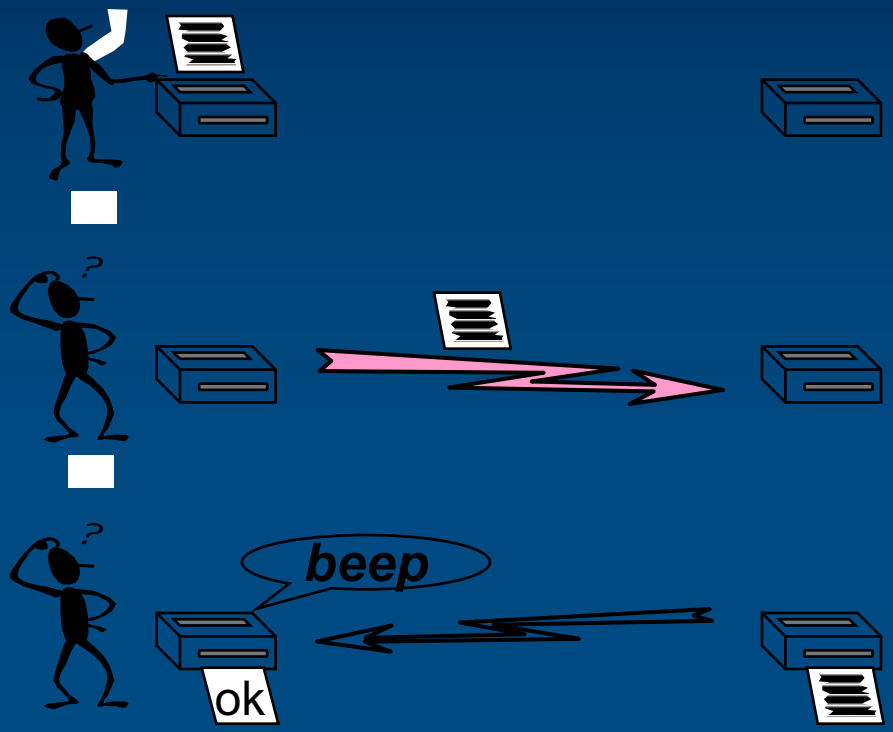
# Synchronous Sends

- The sender sends data and waits until it gets an information that the message is received.



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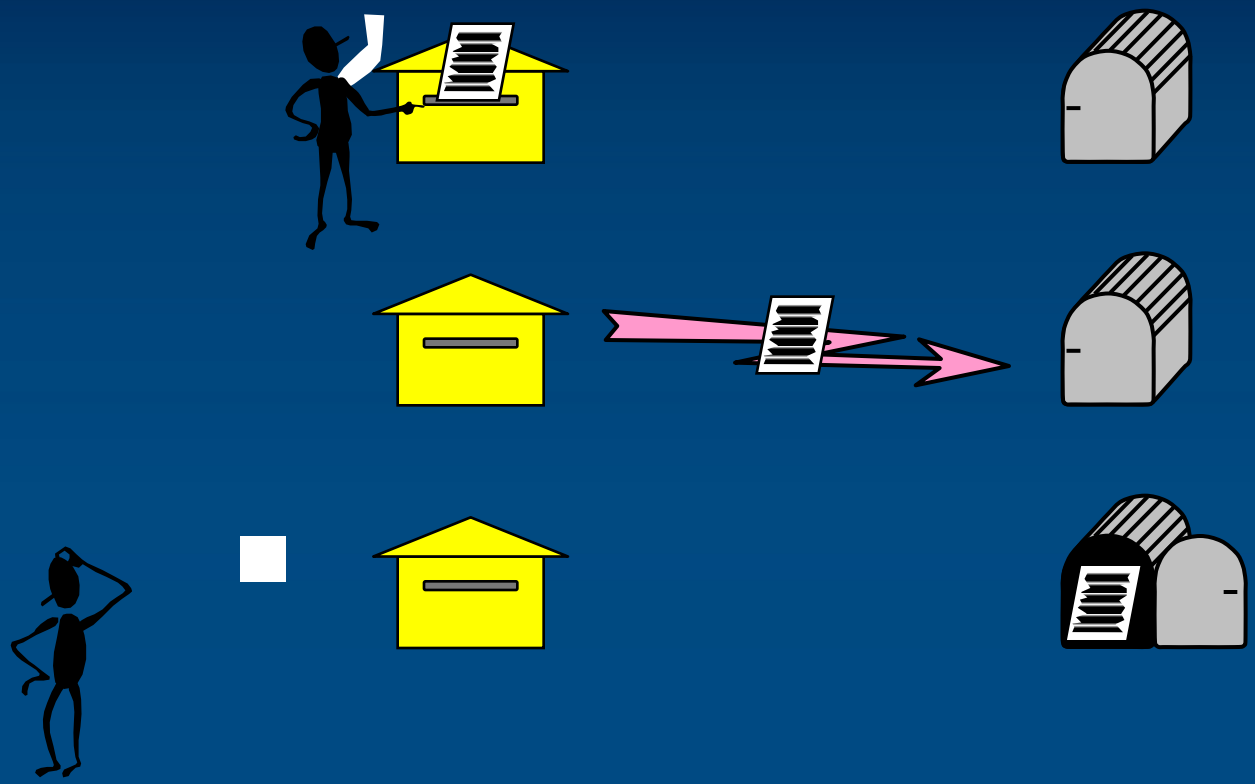
# Buffered = Asynchronous Sends

- Only know when the message has left.



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# Blocking Operations

- Some sends/receives may **block** until another process acts:
  - synchronous send operation **blocks until** receive is issued;
  - receive operation **blocks until** message is sent.
- Blocking subroutine returns only when the operation has completed.

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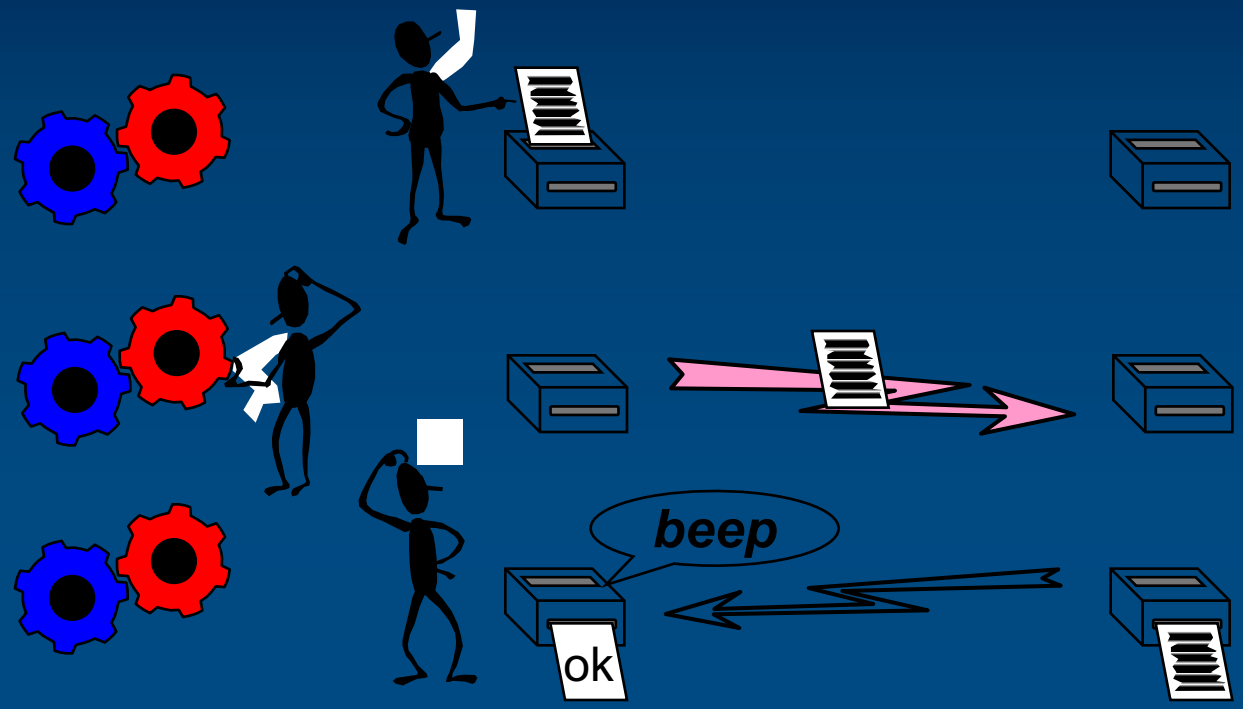
# Non-Blocking Operations

- Non-blocking operations return immediately and allow the sub-program to perform other work.



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# Collective Communications

- Collective communication routines are higher level routines.
- Several processes are involved at a time.
- May allow **optimized internal** implementations, e.g., tree based algorithms

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# Broadcast

- A one-to-many communication.

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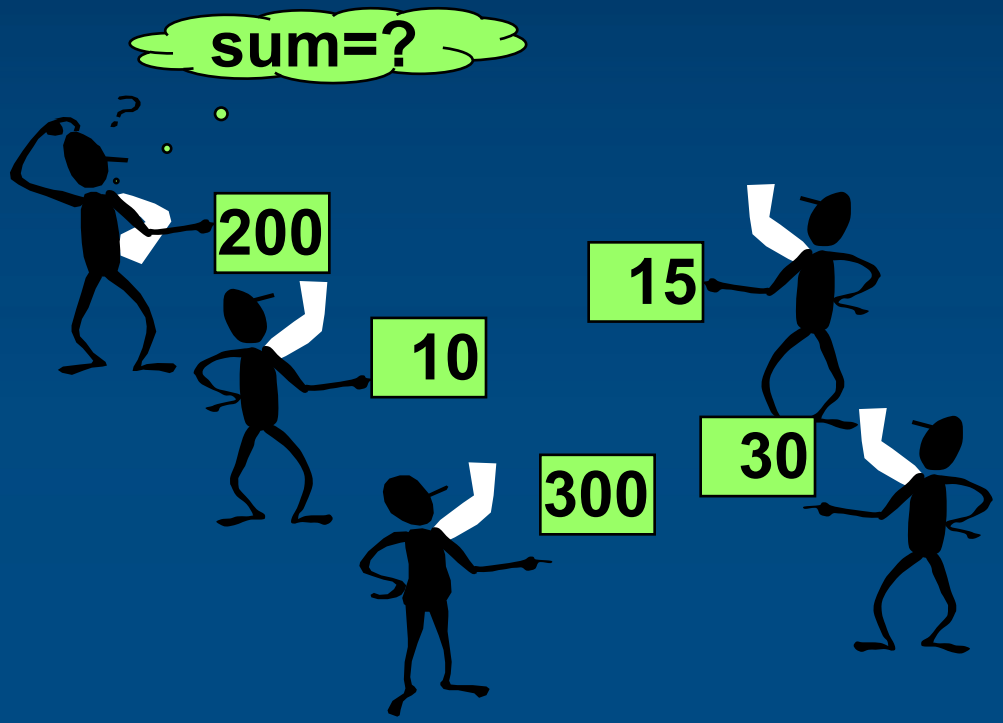
# Reduction Operations

- Combine data from several processes to produce a single result.



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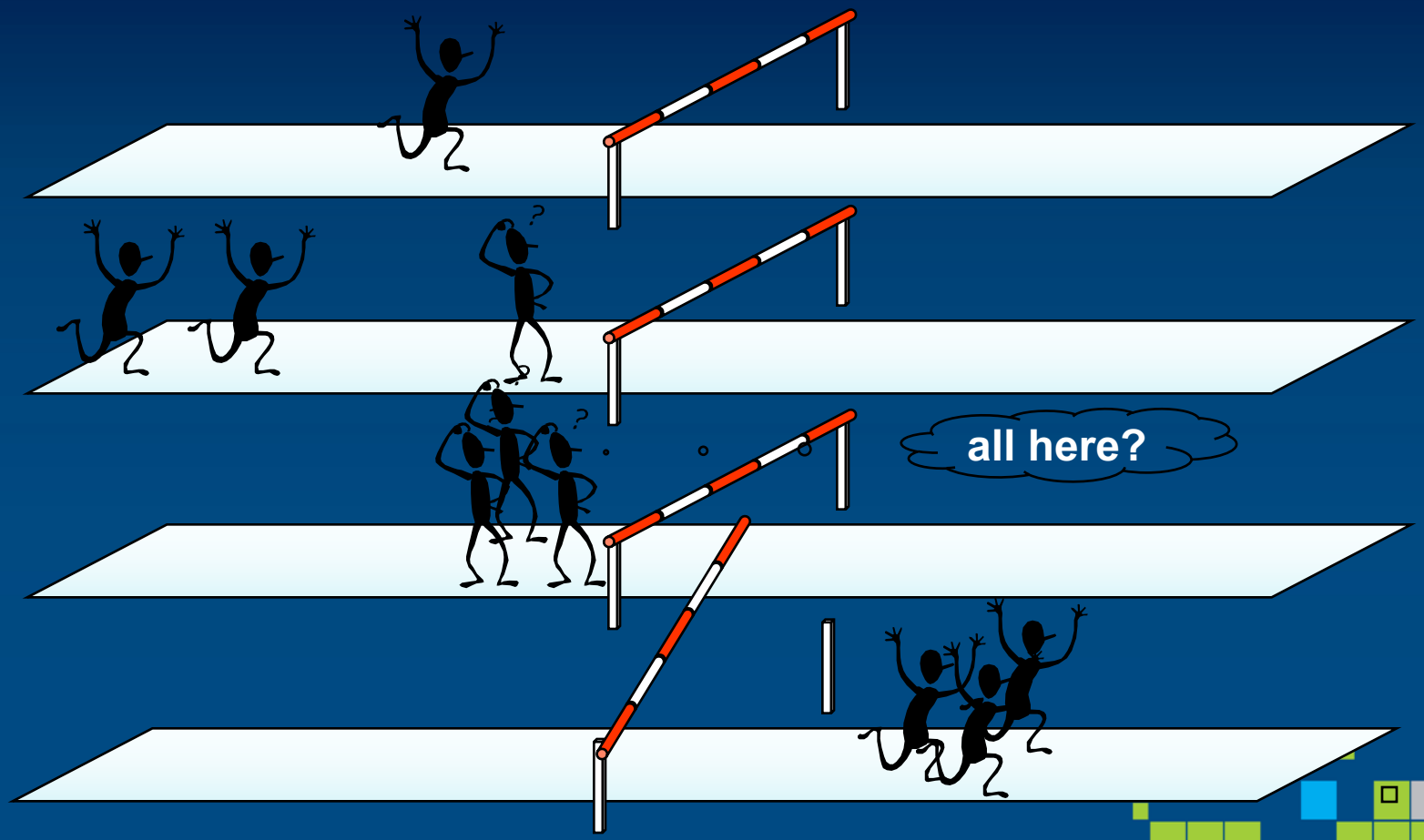
# Barriers

- Synchronize processes.



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# Goals and Scope of MPI

- MPI's prime goals
  - To provide a message-passing interface.
  - To provide source-code portability.
  - To allow efficient implementations.
- It also offers:
  - A great deal of functionality.
  - Support for heterogeneous parallel architectures.
- With MPI-2/MPI-3:
  - Important additional functionality.
  - Backward compatibility with MPI-1.