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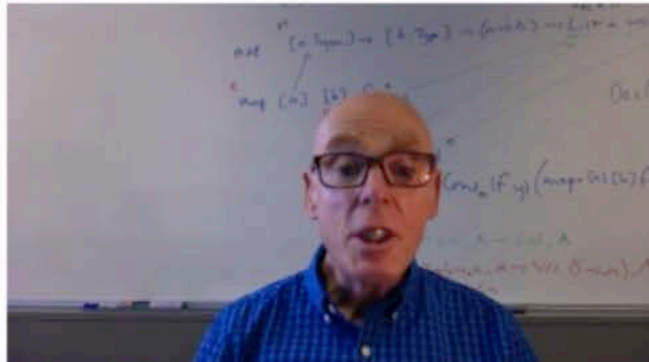
Message-passing concurrency



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Erlang rationale?

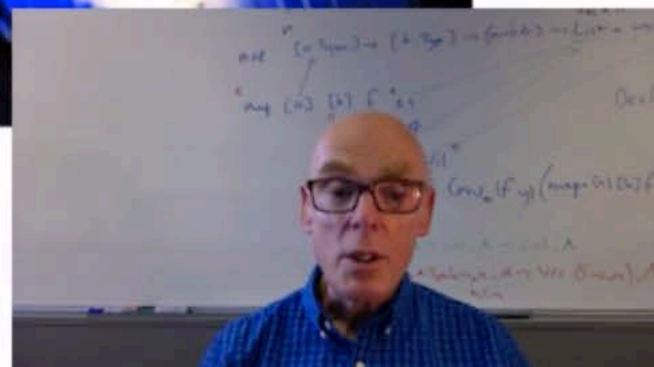
Designed by Ericsson for telecoms systems.

These must be …

… concurrent,

… high-availability, and

… fault-tolerant.



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Erlang rationale?

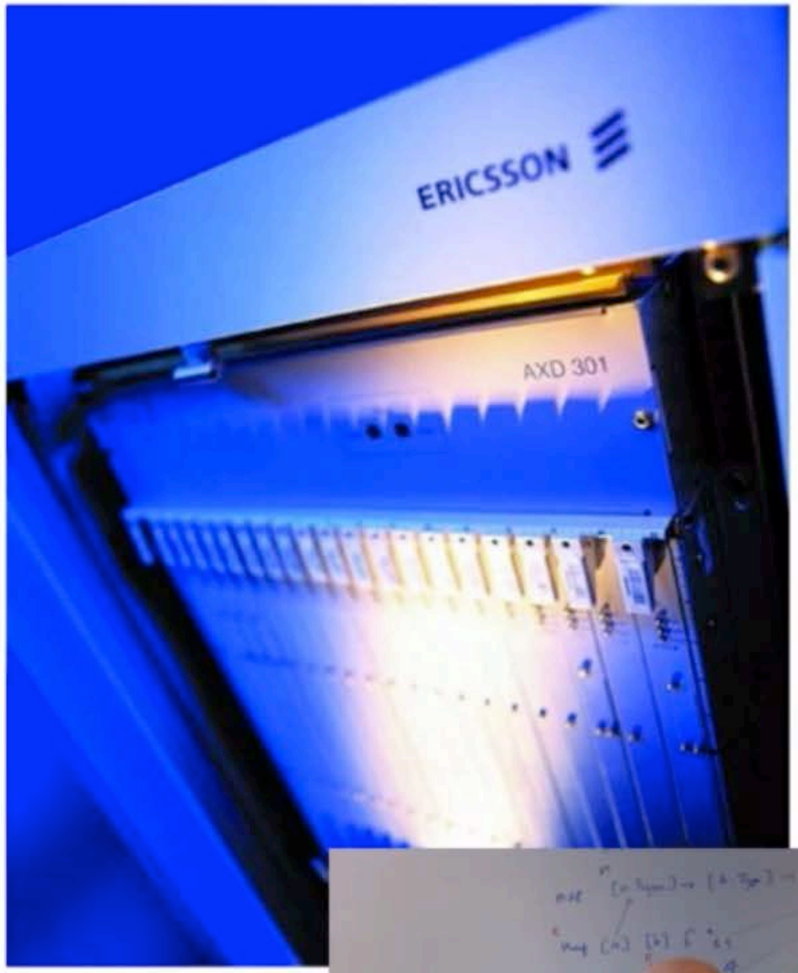
Used today by WhatsApp!, Cisco, Bet365, …

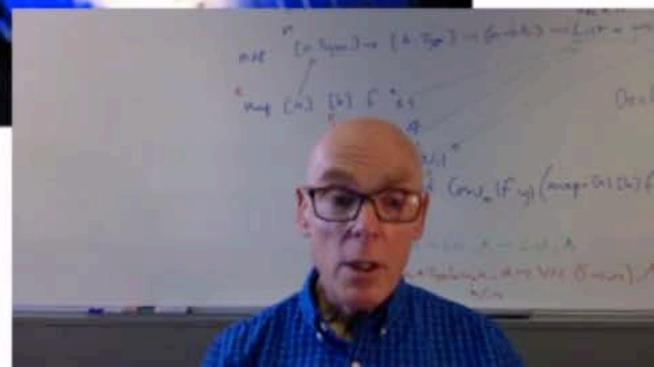
Because it is …

… concurrent,

… high-availability, and

… fault-tolerant.





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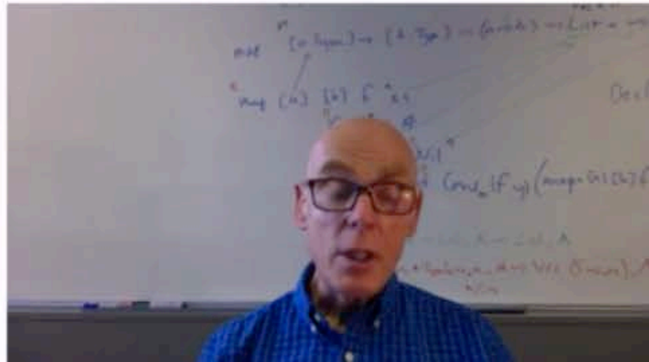
Based on functional programming

Functional is simpler: values and not references, pointers etc.

Functional supports high-level patterns e.g. map/reduce.

With no side-effects ("immutable data") algorithms clearer.



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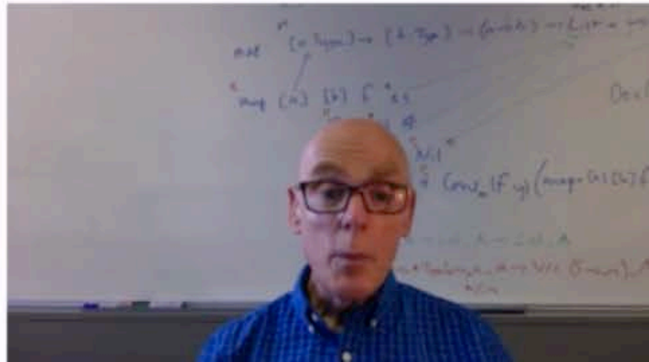
Immutability as a design pattern

Structures whose state doesn't change …

… if you want a different structure, create a new one.

Thread-safe programming … safe caching and sharing … consistency



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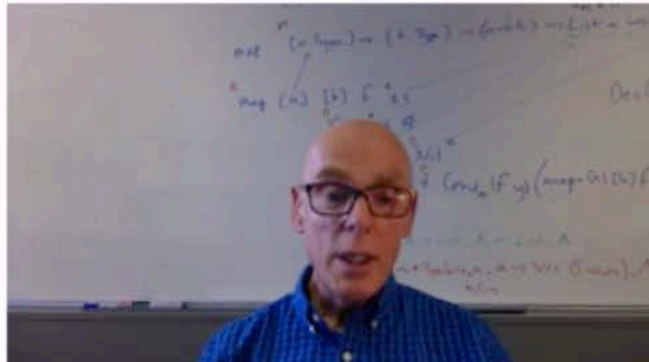
A pragmatic approach to side-effects

At its core, Erlang is functional …

…it does allow some side-effects (e.g. communication) …

… but not others (no updatable Java-style variables).



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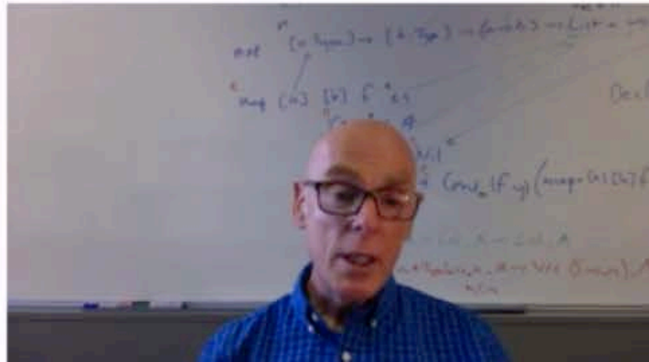
Concurrency

Modularity: different "processes" in different processes.

Robustness: "let it fail" and others processes sort it out.

Concurrency for design (independence) …

… versus parallelism for efficiency (happen at same time).



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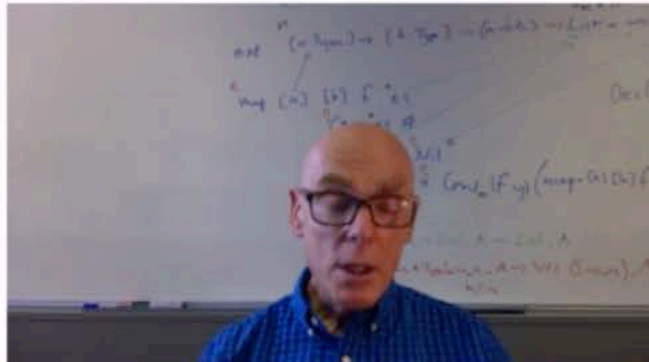
Message-passing concurrency

Different concurrent processes "share nothing" …

…and only communicate by passing messages.

No worries about shared state, thread safety, …



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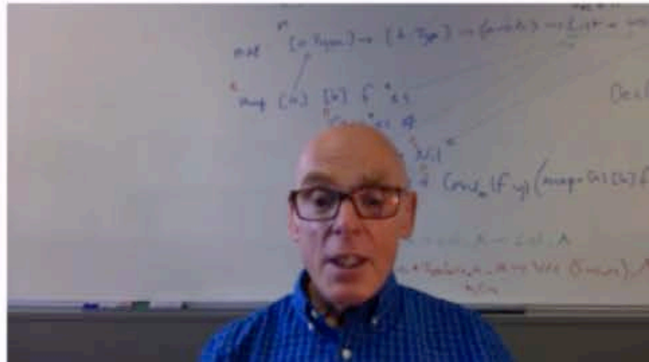
A beautiful design

Mailboxes and message handling

Process errors and trapping exits

OTP generics

Concurrency and distribution

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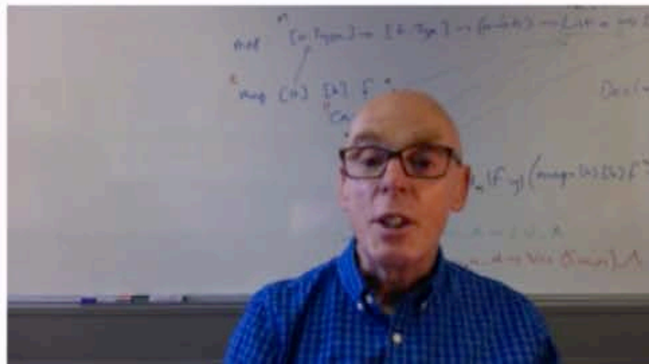
Processes and messages



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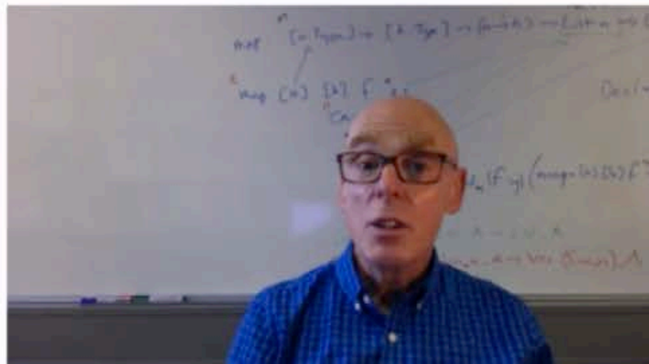

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The "actor model"

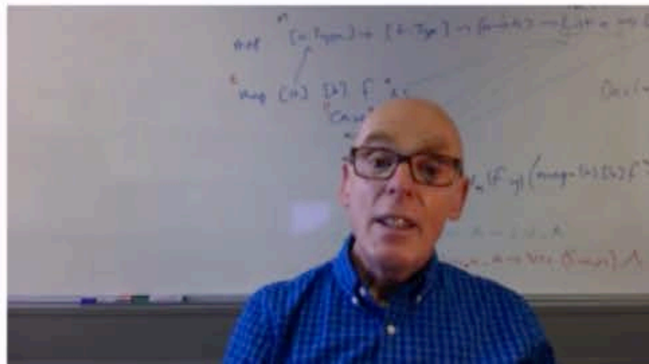
Carl Hewitt's model for the foundations of computation …

… everything is an actor

… actors communicate by messages

… actors can create other actors

… and change behaviour according to messages.



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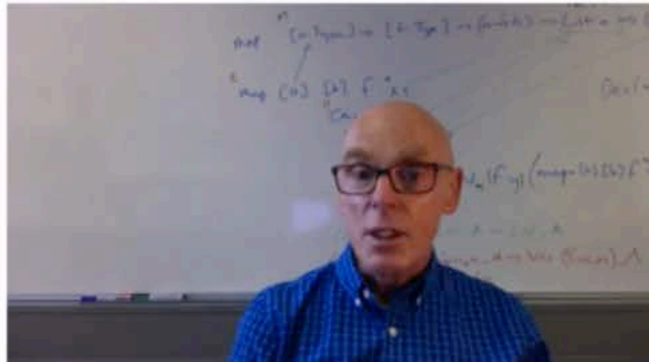
The design of Erlang's concurrency

Erlang designed to build solutions in a particular problem space.

Choices to support that … the roads not chosen.



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Processes *versus* threads

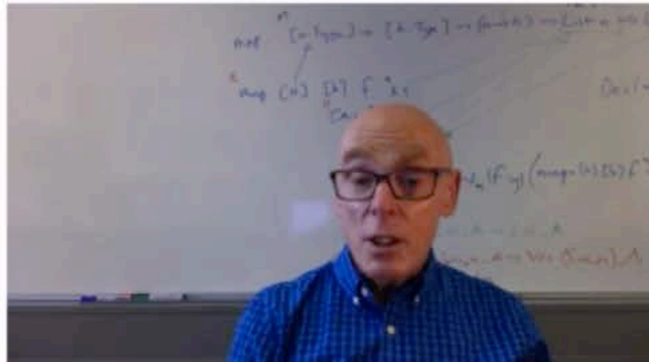
Processes *share nothing* with each other.

In the virtual machine, not the operating system … like "green threads" but …

…more lightweight than threads

…more numerous

… more control: stack, heap and garbage collection per process.



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Synchronous *versus* asynchronous

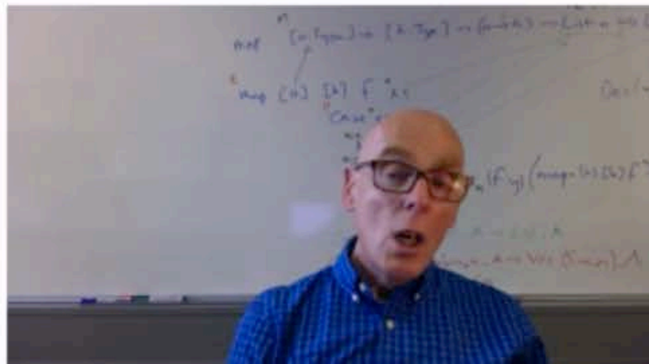
Message send and message receive are decoupled.

… avoids a common source of deadlock

…directly supports processes distributed across a network

…supports more complex message handling

…can simulate synchrony through send/receive protocol



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Identifiers *versus* channels

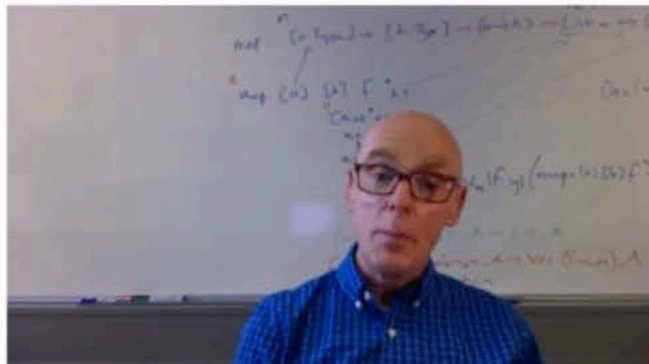
Messages are sent to a particular process id (Pid) …

… rather than along a channel between processes.

The communication structure is less evident in the program …

… but supports dynamic systems more readily.

Named processes give more visible long-lived structures.



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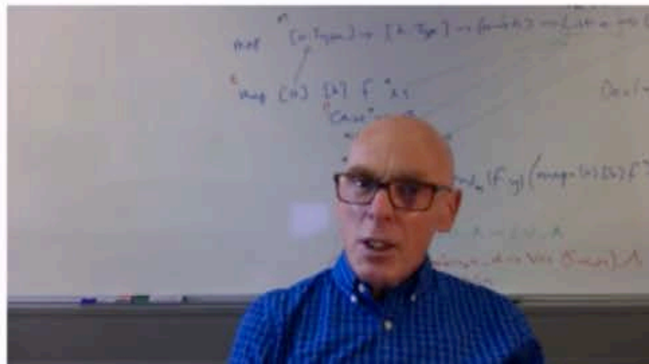
Concurrency *versus* parallelism

Concurrency means the possibility of running independently, perhaps at the same time.

On a single processing element, concurrent processes timeshare, mediated by a scheduler.

On a multicore processor, there is – potentially at least – concurrent activity on each core, with each scheduled separately.



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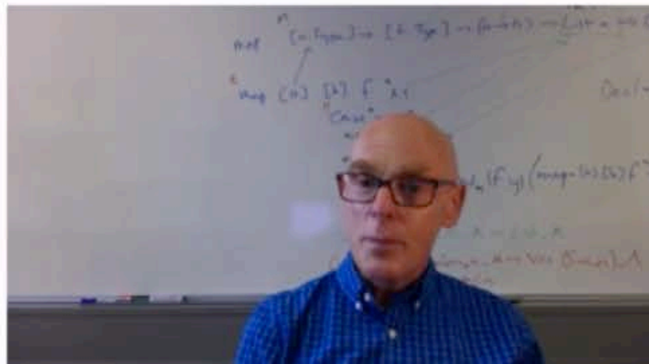


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Processes and messages in practice

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Erlang concurrency in a nutshell

`spawn` – create a process

`!` – send a message

`self()` – give the Process Identifier (Pid) of a process

`receive` – handle a message

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What is a process?

A process is a separate computation

… running in its own space

… time-sharing with other processes

A process runs an Erlang function

… and terminates when / if that function terminates

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`spawn` – create a process

```
spawn(Mod,Fun,Args)
```

`Mod` is a module,

`Fun` is a function in `Mod`,

`Args` is a list of arguments to pass to `Fun` at startup.

For example:

```
spawn(foo,bar,[])
```

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`spawn` returns a process id

A call like

```
spawn(Mod,Fun,Args)
```

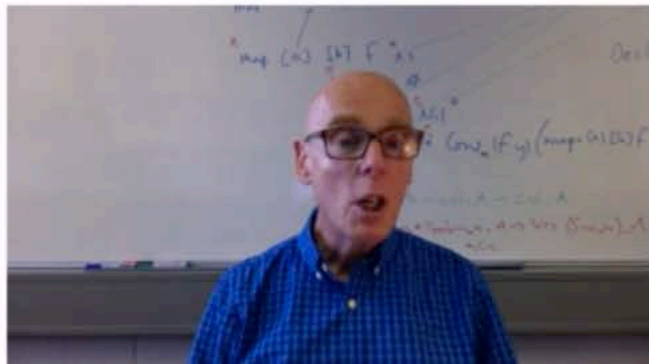
returns the process id (Pid)
of the process created.

It is typically captured like this:

```
Proc = spawn(foo,bar,[])
```

```
-module(foo).
-export([bar/0]).

bar() ->
  timer:wait(500),
  io:format("bar started~n"),
  io:format("bar working~n"),
  io:format("bar finished~n").
```



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70% 13:12

foo.erl

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```
-module(foo).
-export([bar/0,bar/1,baz/0,bazz/0]).

bar() ->
  timer:sleep(500),
  io:format("bar started~n"),
  io:format("bar working~n"),
  io:format("bar finished~n").

bar(Pid) ->
  Pid ! "bar started~n",
  Pid ! "bar working~n",
  Pid ! "bar finished~n".

baz() ->
  receive
    Msg ->
      io:format("got: ~s~n", [Msg])
  end,
  baz().

bazz() ->
  receive
    stop ->
      io:format("stopped~n");
    Msg ->
      io:format("got: ~s~n", [Msg]),
      bazz()
  end.
```

-:--- foo.erl All (29,0) (Erlang EXT Flymake)

No further undo information

simonthompson — xterm — bash

%

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foo.erl

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```

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```
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[hipe] [kernel-poll:false]

Eshell V8.0  (abort with ^G)
1> c(foo).
{ok,foo}
2> spawn(foo,bar,[]).
<0.64.0>
bar started
bar working
bar finished
3> spawn(foo,bar,[]).
<0.66.0>
bar started
bar working
bar finished
4>
```

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`!` – send a message

`Pid ! Msg`

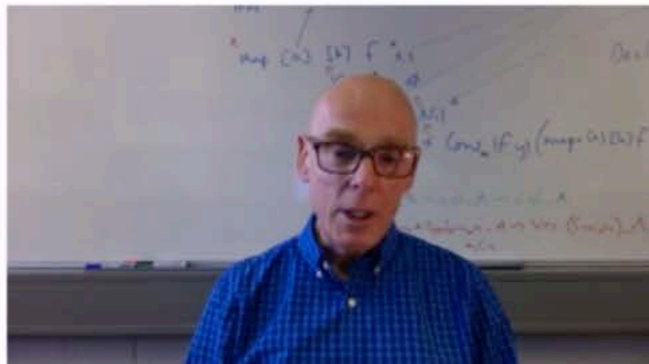
sends the message `Msg` to the process with process id `Pid` ...

We say "sends `Msg` to `Pid`".

The effect is to put `Msg` into the mailbox of process `Pid`.

```
-module(foo).
-export([bar/1]).

bar(Pid) ->
  Pid ! "bar started~n",
  Pid ! "bar working~n",
  Pid ! "bar finished~n".
```



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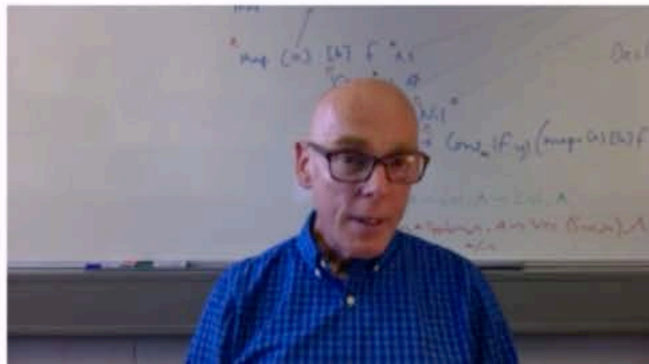
`self()` – what's my Pid?

`self()` gives the `Pid` of the process in which it's called.

In particular, we can get the Pid of the Erlang shell process by calling `self()` there.



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foo.erl

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```
-module(foo).
-export([bar/0,bar/1,baz/0,bazz/0]).

bar() ->
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```

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bar finished
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bar started
bar working
bar finished
4> spawn(foo,bar,[self()]).
<0.68.0>
5> flush().
Shell got "bar started~n"
Shell got "bar working~n"
Shell got "bar finished~n"
ok
6>
```

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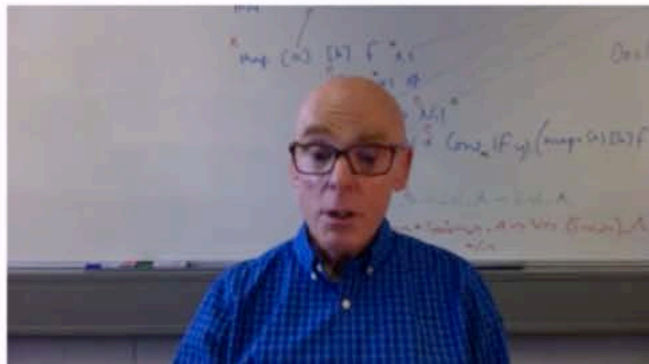
`receive` – receive a message

```
receive
  Msg -> … handle Msg …
end
```

takes the message `Msg` out of the mailbox and handles it.



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  Msg -> … handle Msg …
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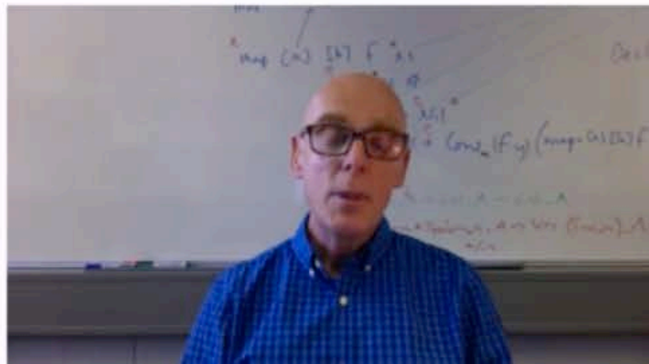
```

takes the message `Msg` out of the mailbox and handles it.

```
-module(foo).
-export([baz/0]).

baz() ->
  receive
    Msg ->
      io:format("got: ~s~n",[Msg])
  end,
  baz().
```



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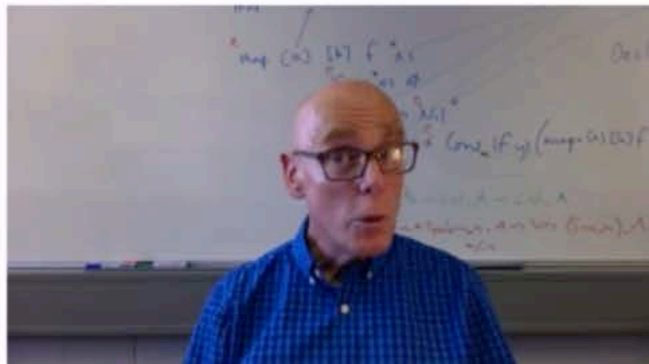
`receive` – receive a message

The general `receive` construct lets us pattern match on messages and choose between alternatives.

Just like a `case` statement.



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The general `receive` construct lets us pattern match on messages and choose between alternatives.

Just like a `case` statement.

```
-module(foo).
-export([bazz/0]).

bazz() ->
  receive
    stop ->
      io:format("stopped~n");
    Msg ->
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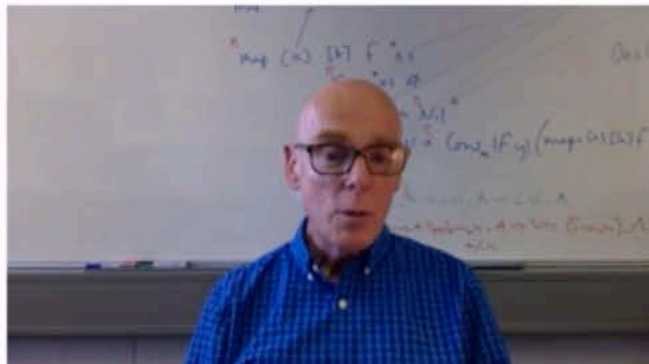
      bazz()
  end.
```



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foo.erl

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```
-module(foo).
-export([bar/0,bar/1,baz/0,bazz/0]).

bar() ->
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-:--- foo.erl All (29,0) (Erlang EXT Flymake)

No further undo information

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5> flush().
Shell got "bar started~n"
Shell got "bar working~n"
Shell got "bar finished~n"
ok
6> Bazz
```

Terminal Shell Edit View Window Help

foo.erl

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```
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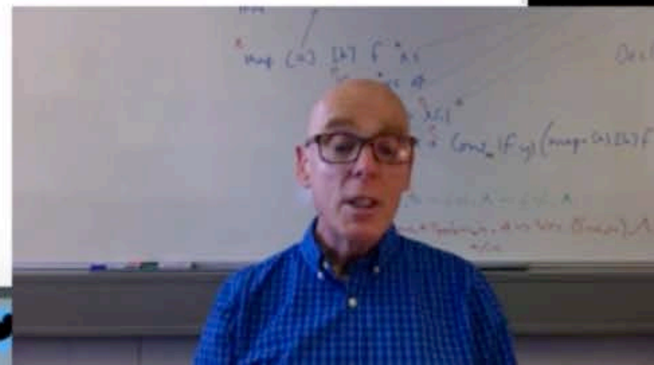
bar finished
4> spawn(foo,bar,[self()]).
<0.68.0>
5> flush().
Shell got "bar started~n"
Shell got "bar working~n"
Shell got "bar finished~n"
ok
6> Bazz = spawn(foo,bazz,[]).
<0.71.0>
7> Bazz ! hello.
got: hello
hello
8> Bazz ! ola .
got: ola
ola
9> Bazz ! stop.
stopped
stop
10>
```



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  baz().

bazz() ->
  receive
    stop ->
      io:format("stopped~n");
    Msg ->
      io:format("got: ~s~n", [Msg]),
      bazz()
  end.
```

-:--- foo.erl All (29,0) (Erlang EXT Flymake)

No further undo information

simonthompson — xterm — beam.smp -- -root /usr/local/lib/erlang -progname erl -- -home ~ -- ▸ erl_child_setup

```
% erl
Erlang/OTP 19 [erts-8.0] [source-6dc93c1] [64-bit] [smp:8:8] [async-threads:10]
[hipe] [kernel-poll:false]

Eshell V8.0  (abort with ^G)
1> c(foo).
{ok,foo}
2> spawn(foo,bar,[]).
<0.64.0>
bar started
bar working
bar finished
3> spawn(foo,bar,[]).
<0.66.0>
bar started
bar working
bar finished
4> spawn(foo,bar,[self()]).
<0.68.0>
5> flush().
Shell got "bar started~n"
Shell got "bar working~n"
Shell got "bar finished~n"
ok
6> Bazz = spawn(foo,bazz,[]).
<0.71.0>
7> Bazz ! hello.
got: hello
hello
8> Bazz ! ola .
got: ola
ola
9> Bazz ! stop.
stopped
stop
10> Bazz ! ola.
ola
11>
```

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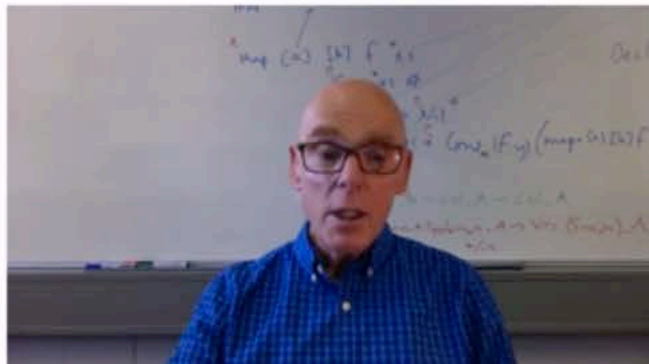
Erlang concurrency in a nutshell

`spawn` – create a process

`!` – send a message

`self()` – give the Process Identifier (Pid) of a process

`receive` – handle a message

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Joe Armstrong

EXPERT SYSTEM DEVELOPER, AND ONE OF THE
CREATORS OF ERLANG AT ERICSSON

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```
area({square,X}) ->
    X*X;
area({rectangle,X,Y}) ->
    X*Y.
```

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```
{square,X} ->
    X*X;
{rectangle,X,Y} ->
    X*Y.
```

```
area({square,X}) ->
    X*X;
area({rectangle,X,Y}) ->
    X*Y.
```

```
area() ->
    receive
      {square,X} ->
        X*X;
      {rectangle,X,Y} ->
        X*Y
    end,
    area().
```

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```
Pid = spawn(demo1, area, []),
Pid ! {square, 10}
```

```
-module(demo1).
-export([area/0]).

area() ->
    receive
      {square,X} ->
        X*X;
      {rectangle,X,Y} ->
        X*Y
    end,
    area().
```

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```
area() ->
    receive
      {square,X} ->
        print(X*X);
      {rectangle,X,Y} ->
        print(X*Y)
    end,
    area().
```

Return to sender

```
Pid = spawn(Mod, area, []),
Pid ! {self(), {square, 10}},
receive
   Reply ->
      Reply
end.
```

```
-module(demo2).
-export([area/0]).

area() ->
   receive
     {From, {square,X}} ->
       From ! X*X;
     {From, {rectangle,X,Y}} ->
       From ! X*Y
   end,
   area().
```

Return to sender

```
Pid = spawn(Mod, area, []),
Pid ! {self(), {square, 10}},
receive
   {Pid, Reply} ->
      Reply
end.
```

```
-module(demo2).
-export([area/0]).

area() ->
   receive
     {From, {square,X}} ->
       From ! {self(), X*X};
     {From, {rectangle,X,Y}} ->
       From ! {self(), X*Y}
   end,
   area().
```

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Four concurrency primitives

- `Pid = spawn(…)`
- `Pid ! Message`
- `receive Pattern -> Actions; … end`
- `self()`

```
receive
    Pattern1 ->
      Actions1;
    …
    PatternN ->
      ActionsN
after Time ->
    TimeoutActions
end
```

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Registered processes

Only the parent knows its child

```
Pid = spawn(…)

Pid = spawn()
register(Name, Pid)

Pid = whereis(Name)
```