PSC 2024/25 (375AA, 9CFU)

Principles for Software Composition

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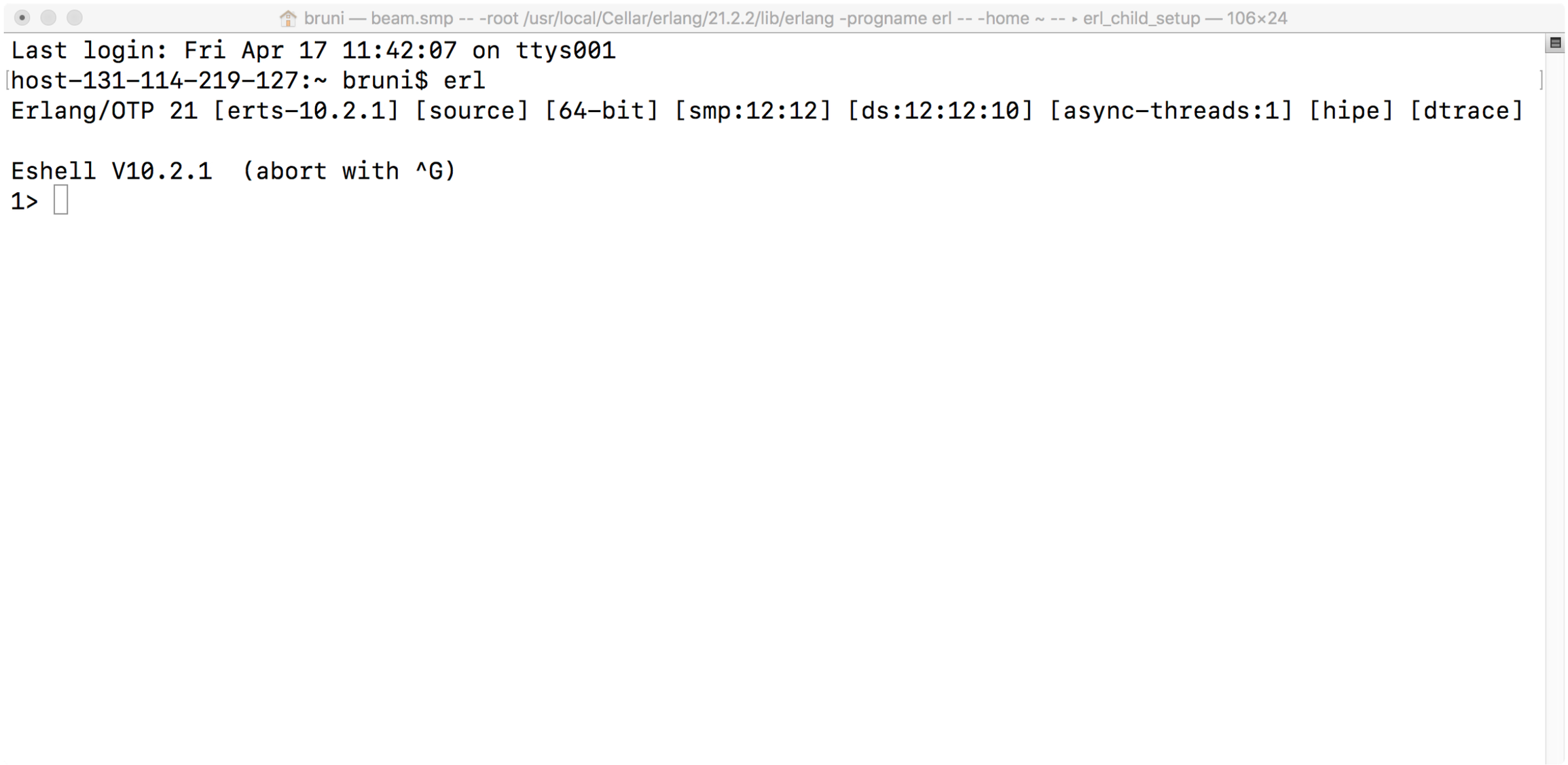
16a - Erlang

erl session


bruni — beam.smp -- -root /usr/local/Cellar/erlang/21.2.2/lib/erlang -progname erl -- -home ~ -- ▸ erl_child_setup — 106×24
Last login: Fri Apr 17 11:42:07 on ttys001
host-131-114-219-127:~ bruni$ erl
Erlang/OTP 21 [erts-10.2.1] [source] [64-bit] [smp:12:12] [ds:12:12:10] [async-threads:1] [hipe] [dtrace]
Eshell V10.2.1 (abort with ^G)
1>

erl session

```
Erlang/OTP 26 [erts-14.0.2] [source] [64-bit] [smp:12:12]
[ds:12:12:10] [async-threads:1] [jit:ns] [dtrace]

Eshell V14.0.2 (press Ctrl+G to abort, type help(). for help)

% First of all, Erlang is a functional programming language.

% Expressions must be terminated with a period
% followed by whitespace (line break, a space etc.),
% otherwise they won't be executed.
% Legacy: Erlang was implemented directly in Prolog.

1> 2 + 15.
17
2> 49 * 100.
4900
3> 5 / 2.
2.5
4> 5 div 2.
2
5> 5 rem 2.
1
```

erl session

```
% NUMBERS
% - integers
% - floating point (64-bit IEEE 754-1985 double precision)
% mathematical operators will handle transparently for you.

% ATOMS
% Atoms are literals, constants with their own name for value.
% You can't play with it,
% you can't change it,
% you can't smash it to pieces
% An atom should be enclosed in single quotes (')
% if it does not begin with a lower-case letter
% or if it contains characters other than alphanumeric, _, @
% an atom with single quotes is exactly the same as a
% similar atom without them.

6> monday.
monday
7> 'monday'.
monday
8> 'hello \n my friend'.
'hello \n my friend'
```

erl session

```
% Some atoms are reserved words. These are:
% after                                case                                of
% and                                  catch                               or
% andalso                              cond                                orelse
% band                                 div                                 query
% begin                                end                                 receive
% bnot                                 fun                                 rem
% bor                                  if                                  try
% bsl                                  let                                 when
% bsr                                  not                                 xor
% bxor
%
% TERMS
% * Constant data types
%   - Numbers
%   - Atoms
%   - Pids (process identifiers)
%   - References (for storing system unique references)
%
% * Compound data types
%   - Tuples (fixed number of comma separated terms, curly brackets)
%   - Lists (variable number of comma separated terms, square brackets)
```

erl session

```
% Tuples (fixed number of comma separated terms, curly brackets)

9> {a,b,c}.
{a,b,c}

% Lists (variable number of comma separated terms, square brackets)

10> [a,b,c].
[a,b,c]

% Strings

11> "abc".
"abc"
12> [97,98,99].
"abc"
13> [97,98,99,7].
[97,98,99,7]
```

erl session

```
% BOOLEAN ALGEBRA: true and false are just atoms!
% and / or will always evaluate both arguments.
% andalso / orelse evaluates the second argument if needed.

14> true.
true
15> false.
false
16> true and false.
false
17> false or true.
true
18> not false.
true
19> true xor false.
true
20> true and pippo.
** exception error: bad argument
     in operator  and/2
        called as true and pippo
21> true orelse pippo.
true
22> false andalso pippo.
false
```

erl session

```
% VARIABLES
% variables begin with an uppercase letter or _
% use _ when you do not care about their value
%
% the variable _ won't ever store any value
%
% you can assign a value to a variable exactly once;
% then you can 'pretend' to assign a value to a variable
% if it's the same value it already has.
% If it's different, Erlang will complain.
```

```
23> One.
* 1:1: variable 'One' is unbound
24> One = 1.
1
25> One = 2.
** exception error: no match of right hand side value 2
```

erl session

```
% The = operator has the role of comparing values
% and complaining if they're different.
% If they're the same, it returns the value
%
% The following parses Un = (Ein = (Uno = (One = 1))).
26> Un = Ein = Uno = One = 1.
1

% to display all variable bindings: b()
27> b().
Ein = 1
One = 1
Un = 1
Uno = 1
ok

% To 'erase' the value assigned to a variable: f(.)
28> f(Ein).
ok
29> b().
One = 1
Un = 1
Uno = 1
ok
```

erl session

```
30> Two = One + One.
2
31> Two = 2.
2

% To clear all variable names: f()

32> f().
ok
33> b().
ok
```

erl session

```
% To see the list of commands: help()

34> help().
** shell internal commands **
b()         -- display all variable bindings
e(N)        -- repeat the expression in query <N>
f()         -- forget all variable bindings
f(X)        -- forget the binding of variable X
h()         -- history
h(Mod)      -- help about module
h(Mod,Func)-- help about function in module
h(Mod,Func,Arity) -- help about function with arity in module
ht(Mod)     -- help about a module's types
ht(Mod,Type) -- help about type in module
ht(Mod,Type,Arity) -- help about type with arity in module
hcb(Mod)    -- help about a module's callbacks
hcb(Mod,CB) -- help about callback in module
hcb(Mod,CB,Arity) -- help about callback with arity in module
history(N) -- set how many previous commands to keep
results(N) -- set how many previous command results to keep
catch_exception(B) -- how exceptions are handled
v(N)        -- use the value of query <N>
rd(R,D)     -- define a record
rf()        -- remove all record information
rf(R)       -- remove record information about R
rl()        -- display all record information
rl(R)       -- display record information about R
rp(Term)    -- display Term using the shell's record information
rr(File)    -- read record information from File (wildcards allowed)
rr(F,R)     -- read selected record information from file(s)
rr(F,R,O)   -- read selected record information with options
```

erl session

```
** commands in module c **
bt(Pid)     -- stack backtrace for a process
c(Mod)      -- compile and load module or file <Mod>
cd(Dir)     -- change working directory
flush()     -- flush any messages sent to the shell
help()      -- help info
h(M)        -- module documentation
h(M,F)      -- module function documentation
h(M,F,A)    -- module function arity documentation
i()         -- information about the system
ni()        -- information about the networked system
i(X,Y,Z)    -- information about pid <X,Y,Z>
l(Module)   -- load or reload module
lm()        -- load all modified modules
lc([File]) -- compile a list of Erlang modules
ls()        -- list files in the current directory
ls(Dir)     -- list files in directory <Dir>
m()         -- which modules are loaded
m(Mod)      -- information about module <Mod>
mm()        -- list all modified modules
memory()    -- memory allocation information
memory(T)   -- memory allocation information of type <T>
nc(File)    -- compile and load code in <File> on all nodes
nl(Module) -- load module on all nodes
pid(X,Y,Z) -- convert X,Y,Z to a Pid
pwd()       -- print working directory
q()         -- quit - shorthand for init:stop()
regs()      -- information about registered processes
nregs()     -- information about all registered processes
uptime()    -- print node uptime
xm(M)       -- cross reference check a module
y(File)     -- generate a Yecc parser
** commands in module i (interpreter interface) **
ih()        -- print help for the i module
true
```

erl session

```
% TERM COMPARISON
% greater than (coerce integers to float if needed)
35> 4 > 3.
true

% less than (coerce integers to float if needed)
36> 4 < 5.
true

% greater than or equal to (coerce integers to float if needed)
37> 4 >= 3.
true

% equal to or less than !! (coerce integers to float if needed)
% (be careful: source of many syntax errors!!)
38> 4 <= 5.
* 1:3: syntax error before: '<='
38> 4 =< 5.
true
```

erl session

```
% equal to (coerce integers to float if needed)
39> 3 == 3.
true

% not equal to (coerce integers to float if needed)
40> 3 /= 3.
false

% equal to (coerce integers to float if needed)
41> 3 == 3.0.
true

% not equal to (coerce integers to float if needed)
42> 3 /= 3.0.
false

% exact equal to (no coercion)
43> 3 =:= 3.0.
false

% exact not equal to (no coercion)
44> 3 =/= 3.0.
true
```

erl session

```
% Erlang will let you compare anything with anything.
% Erlang has no such things as boolean true and false.
% The terms true and false are atoms
%
% The ordering of each element in a comparison is the following:
%
% number < atom  < fun  < pid < tuple < list
%
% Tuples are ordered first by their size then by their elements.
% Lists are ordered by comparing heads, then tails.
```

```
45> 1 < a.
true
46> a < {a}.
true
47> {a} < [a].
true

% Complete order
%
% number < atom < reference < fun < port < pid < tuple < list
% < bit string
```

erl session

```
% PATTERN MATCHING
% Pattern = Expression

48> X=10, Y=4.
4
49> Point = {X,Y}.
{10,4}
50> {A,B} = Point.
{10,4}
51> b().
A = 10
B = 4
Point = {10,4}
X = 10
Y = 4
ok
52> {A1,_} = Point.
{10,4}
53> A1.
10
54> {_,_} = {1,2,3}.
** exception error: no match of right hand side value {1,2,3}
```

erl session

```
% LISTS
% Lists can contain anything!

55> [1, 2, 3, {numbers,[4,5,6]}, 5.34, atomo].
[1,2,3,{numbers,[4,5,6]},5.34,atomo]

% concatenation: ++ operator
56> [1,2,3] ++ [4,5].
[1,2,3,4,5]

% The operator -- removes elements from a list:
57> [1,2,3,4,5] -- [1,4].
[2,3,5]
58> [1,2,3,1,2,3] -- [1,1,2].
[3,2,3]
59> [1,2,3,1,2,3] -- [1,1,2,5].
[3,2,3]
60> [1,2,3] -- [1,2] -- [3].
[3]
% the above reads [1,2,3] -- ([1,2] -- [3]).
61> ([1,2,3] -- [1,2]) -- [3].
[]
```

erl session

```
% BIF (built-in functions)
% head of a list
62> hd([1,2,3,4,5]).
1

% tail of a list
63> tl([1,2,3,4,5]).
[2,3,4,5]

% length of a list
64> length([1,2,3,4,5]).
5

% pattern matching on lists [Head|Tail]
65> List = [2,3,4].
[2,3,4]
66> NewList = [1|List].
[1,2,3,4]
67> [Head|Tail] = NewList.
[1,2,3,4]
```

erl session

```
68> b().
A = 10
A1 = 10
B = 4
Head = 1
List = [2,3,4]
NewList = [1,2,3,4]
Point = {10,4}
Tail = [2,3,4]
X = 10
Y = 4
ok
```

erl session

```
% The | we used is named the cons operator (constructor).
% In fact, any list can be built with only cons and values:

69> [1 | [2 | [3 | [] ] ] ].
[1,2,3]
70> [1|2].
[1|2]
71> [I,J] = [1|[2]].
[1,2]
72> [I,J] = [1|2].
** exception error: no match of right hand side value [1|2]
73> [I1,J1] = [1|2].
** exception error: no match of right hand side value [1|2]
74> [I1|J1] = [1|2].
[1|2]

% [1 | 2] gives what we call an 'improper list':
% syntactically valid, are of very limited use.
```

erl session

```
75> b().
A = 10
A1 = 10
B = 4
Head = 1
I = 1
I1 = 1
J = 2
J1 = 2
List = [2,3,4]
NewList = [1,2,3,4]
Point = {10,4}
Tail = [2,3,4]
X = 10
Y = 4
ok
```

erl session

```
% List Comprehensions: use ||

76> [2*N || N <- [1,2,3]].
[2,4,6]
77> Z = [ {X,Y} || X <- [a,b,c], Y <- [1,2,3,4] ].
[{a,1},
 {a,2},
 {a,3},
 {a,4},
 {b,1},
 {b,2},
 {b,3},
 {b,4},
 {c,1},
 {c,2},
 {c,3},
 {c,4}]
78> [ X || {a,X} <- Z ].
[1,2,3,4]
```

erl session

```
% -module(name).
% This is always the first attribute and statement of a file.
% it's the name of the current module, where name is an atom.
% This is the name you'll use to call functions from other modules.
% The calls are made with the m:f(a) form,
% where m is the module name, f the function, and a the arguments.

-module(adders).
-export([add/3,add/4]).

add(X,Y) -> X + Y.
add(X,Y,Z) -> X + Y + Z.
add(X,Y,Z,U) -> add(X,Y) + add(Z,U).
```

adders.erl

```
1 -module(adders).
2 -export([add/3,add/4]).
3
4 add(X,Y) -> X + Y.
5
6 add(X,Y,Z) -> X + Y + Z.
7
8 add(X,Y,Z,U) -> add(X,Y) + add(Z,U).
9
```

```
% Erlang code is compiled to bytecode to be used by the VM.
% You can call the compiler from many places:
% $ erlc flags file.erl when in the command line,
% compile:file(FileName) when in the shell or in a module,
% c(FileName) when in the shell, etc.

-module(functions).
-compile(export_all).
% export all functions defined in the module
```

erl session

adders.erl

```erlang
-module(adders).
-export([add/3,add/4]).

add(X,Y) -> X + Y.

add(X,Y,Z) -> X + Y + Z.

add(X,Y,Z,U) -> add(X,Y) + add(Z,U).
```

```
83> c(adders).
{ok,adders}
84> adders:add(1,2,3).
6
```

erl session

functions.erl

```erlang
-module(functions).
-compile(export_all).

hello() -> io:format("Hello, world!~n").

```

```
85> c(functions).
functions.erl:2:2: Warning: export_all flag enabled - all functions
will be exported
{ok,functions}
```

erl session

```
19  greet(male, Name) ->
20      io:format("Hello, Mr. ~s!~n", [Name]);
21  greet(female, Name) ->
22      io:format("Hello, Mrs. ~s!~n", [Name]);
23  greet(_, Name) ->
24      io:format("Hello, ~s!~n", [Name]).
```

```
% Defining functions with pattern matching
% Each of these function declarations is called a function clause.
% Function clauses must be separated by semicolons (;)
% together form a function declaration.
%
% the clauses are scanned sequentially, in the order in which occur
% until the first one of them matches the call.
% When a match occurs,
% the expression on the right-hand side of '->' is evaluated,
% variables occurring in the function definition are substituted
% in the right-hand side of the clause before it is evaluated.
```

erl session

```
19  greet(male, Name) ->
20      io:format("Hello, Mr. ~s!~n", [Name]);
21  greet(female, Name) ->
22      io:format("Hello, Mrs. ~s!~n", [Name]);
23  greet(_, Name) ->
24      io:format("Hello, ~s!~n", [Name]).
```

```
% io:format alike printf
% In the string ~ denotes a token
% ~~ is ~
% ~n is line break
% ~s is a string or a bitstring
% ~p prints an erlang term in a nice way (with indentation)
```

erl session

```
19  greet(male, Name) ->
20      io:format("Hello, Mr. ~s!~n", [Name]);
21  greet(female, Name) ->
22      io:format("Hello, Mrs. ~s!~n", [Name]);
23  greet(_, Name) ->
24      io:format("Hello, ~s!~n", [Name]).
```

```
86> functions:greet(male,andrea).
Hello, Mr. andrea!
ok
87> functions:greet(female,andrea).
Hello, Mrs. andrea!
ok
88> functions:greet(child,andrea).
Hello, andrea!
ok
```

erl session

```
36  % define second element of a list
37  second([_,X|_]) -> X.
```

```
89> functions:second([1,2]).
2
90> functions:second([2]).
** exception error: no function clause matching
functions:second([2]) (functions.erl, line 37)
```

erl session

```
137  %%% Higher Order
138  one() -> 1.
139  two() -> 2.
140  % functions:one() .
141  % functions:two() .
142
143  add(X,Y) -> X() + Y().
144  % functions:add(fun functions:one/0 , fun functions:two/0).
```

```
95> functions:add(fun functions:one/0 , fun functions:two/0).
3
```

erl session

```
146  apply(F,X) -> F(X).
```

```
96> Succ = fun(X) -> X+1 end.
#Fun<erl_eval.42.125776118>
97> functions:apply(Succ,3).
4
98> lists:map(Succ,[1,2,3]).
[2,3,4]
```

erl session

recursion.erl

recursion.erl

```erlang
-module(recursion).
-compile(export_all).

%% EXAMPLE: Factorial with different syntax

% with GUARDS and PATTERN MATCHING
fac(0) -> 1;
fac(N) when N > 0  -> N*fac(N-1);
fac(_) -> 0.

% with IFs
fact(N) -> if N == 0 -> 1
           ; N > 0  -> N*fact(N-1)
           ; true -> 0
           end .

% TAIL RECURSION
tail_fac(N) -> tail_fac(N,1).

tail_fac(0,Acc) -> Acc;
tail_fac(N,Acc) when N > 0 -> tail_fac(N-1,N*Acc);
tail_fac(_,_) -> 0.
```

erl session

```erlang
26  %% EXAMPLE: permutations
27
28  perms([]) -> [[]];
29  perms(L)  -> [[H|T] || H <- L, T <- perms(L--[H])].
```

```
99> c(recursion).
recursion.erl:2:2: Warning: export_all flag enabled - all functions
will be exported
{ok,recursion}
100> recursion:perms("abc").
["abc","acb","bac","bca","cab","cba"]
101> recursion:perms("abcdef").
["abcdef","abcdfe","abcedf","abcefd","abcfde","abcfed",
 "abdcef","abdcfe","abdecf","abdefc","abdfce","abdfec",
 "abecdf","abecfd","abedcf","abedfc","abefcd","abefdc",
 "abfcde","abfced","abfdce","abfdec","abfecd","abfedc",
 "acbdef","acbdfe","acbedf","acbefd",
 [...]|...]
```

erl session

```
32  %% EXAMPLE: length of a list
33
34  len([]) -> 0;
35  len([_|T]) -> 1 + len(T).
36
37  tail_len(L) -> tail_len(L,0).
38
39  tail_len([],Acc) -> Acc;
40  tail_len([_|T],Acc) -> tail_len(T,Acc+1).
```

```
42  %% EXAMPLE: replicate
43
44  replicate(0,_) -> [];
45  replicate(N,Term) when N > 0 -> [Term|replicate(N-1,Term)].
46
47  tail_replicate(N,Term) -> tail_replicate(N,Term,[]).
48
49  tail_replicate(0,_,List) -> List;
50  tail_replicate(N,Term,List) when N > 0 -> tail_replicate(N-1, Term, [Term|List]).
```

```
52  %% EXAMPLE: reverse
53
54  reverse([]) -> [];
55  reverse([H|T]) -> reverse(T)++[H].
56  % costs too much!!
57
58  tail_reverse(L) -> tail_reverse(L,[]).
59
60  tail_reverse([],Acc) -> Acc;
61  tail_reverse([H|T],Acc) -> tail_reverse(T, [H|Acc]).
```

erl session

```
% In Erlang, processes belong to the programming language
% and NOT the operating system.

% In Erlang:
% - Creating and destroying processes is very fast.
% - Sending messages between processes is very fast.
% - Processes behave the same way on all operating systems.
% - We can have very large numbers of processes.
% - Processes share no memory and are completely independent.
% - The only way for processes to interact is via message passing.
% For these reasons Erlang is a pure message passing language.
%
% Erlang uses the actor model:
% each actor is a separate process in the virtual machine.
% In Erlang everyone communicates by writing letters and that's it.
% If you were an actor in Erlang's world,
% you would be a lonely person,
% - sitting in a dark room with no window,
% - waiting by your mailbox to get a message.
% Once you get a message,
% - you react to it in a specific way:
% you pay the bills when receiving them,
% you respond to Birthday cards with a "Thank you" letter
% and you ignore the letters you can't understand.
```

erl session

```
% If the shell freezes: ^G
%
% - type in i then c
%   Erlang should stop the currently running code
%   and bring you back to a responsive shell
%
% - j will give you a list of processes running
%   current job marked by a star
%
% - k kills the shell as it is instead of just interrupting it.
%
% - Press s to start a new one.
```

erl session

```
% To start a new process
% - spawn/1, takes a single function and runs it
%   once it's done, it disappears.

102> F = fun() -> 2 + 2 end.
#Fun<erl_eval.43.125776118>
103> spawn(F).
<0.210.0>

% we get a process id
% <0.210.0>
% we can't see the result of the function F.
% We only get its pid.
% That's because processes do not return anything.
% to get the pid of the current process

104> self().
<0.192.0>
```

erl session

```
105> G = fun (X) ->
  ..      timer:sleep(200-X),
  ..      io:format("~p says ~p~n",[self(),X])
  ..      end.
#Fun<erl_eval.42.125776118>
106> G(5).
<0.192.0> says 5
ok
107> [spawn(fun() -> G(X) end) || X <- lists:seq(1,30)].
[<0.215.0>,<0.216.0>,<0.217.0>,<0.218.0>,<0.219.0>,
 <0.220.0>,<0.221.0>,<0.222.0>,<0.223.0>,<0.224.0>,<0.225.0>,
 <0.226.0>,<0.227.0>,<0.228.0>,<0.229.0>,<0.230.0>,<0.231.0>,
 <0.232.0>,<0.233.0>,<0.234.0>,<0.235.0>,<0.236.0>,<0.237.0>,
 <0.238.0>,<0.239.0>,<0.240.0>,<0.241.0>,<0.242.0>,<0.243.0>|...]
<0.244.0> says 30
<0.243.0> says 29
<0.240.0> says 26
<0.242.0> says 28
<0.241.0> says 27
...

% The order doesn't make sense. Welcome to parallelism
```

erl session

```
% to send a message use the bang symbol !
% Pid ! Msg

109> self() ! hello.
hello

% you can send the same message to multiple recipients

110> self() ! self() ! self() ! hello.
hello

% to receive messages

111> receive X -> io:format("got ~p~n",[X]) end.
^G
User switch command (type h for help)
 --> i

 --> c

** exception exit: killed
```

erl session

```
% Let us retry

112> f().
ok
113> self() ! self() ! self() ! hello.
hello
114> receive X -> io:format("got ~p~n",[X]) end.
got hello
ok
115> receive X -> io:format("got ~p~n",[X]) end.
got hello
ok
116> receive X -> io:format("got ~p~n",[X]) end.
got hello
ok
117> receive X -> io:format("got ~p~n",[X]) end.
^G
User switch command (type h for help)
 --> i

 --> c

** exception exit: killed
```

erl session

```
% to see and empty the mailbox: flush()

119> self() ! self() ! self() ! self() ! self() ! bye.
bye
120> flush().
Shell got bye
Shell got bye
Shell got bye
Shell got bye
Shell got bye
ok
```

erl session

counter.erl

counter.erl

```erlang
-module(counter).
-export([start/0,loop/1]).

start() ->
% Pid = spawn(Module,Function,Args)
    spawn(counter, loop, [0]).

loop(Val) ->
    receive
        inc -> loop(Val + 1); % tail recursive call
        reset -> loop(0);  % tail recursive call
        val -> io:format("Val is ~p~n",[Val]),
               loop(Val); % tail recursive call
        stop -> io:format("~p says bye!~n",[self()]);  % NO recursive call
        _ -> loop(Val) % other messages are discarded
    end.
```

```
121> c(counter).
{ok,counter}
122> counter:start().
<0.317.0>
123> Cnt = counter:start().
<0.319.0>
```

erl session

```
123> Cnt = counter:start().
<0.319.0>
124> Cnt ! val.
Val is 0
val
125> Cnt ! inc.
inc
126> Cnt ! Cnt ! Cnt ! Cnt ! inc.
inc
127> Cnt ! val.
Val is 5
val
128> Cnt ! reset.
reset
129> Cnt ! val.
Val is 0
val
130> Cnt ! stop.
<0.319.0> says bye!
stop
131> Cnt ! stop.
stop
132> Cnt ! stop.
stop
133> Cnt ! val.
val
```

counter.erl

```erlang
-module(counter).
-export([start/0,loop/1]).

start() ->
% Pid = spawn(Module,Function,Args)
    spawn(counter, loop, [0]).

loop(Val) ->
    receive
        inc -> loop(Val + 1); % tail recursive call
        reset -> loop(0);  % tail recursive call
        val -> io:format("Val is ~p~n",[Val]),
               loop(Val); % tail recursive call
        stop -> io:format("~p says bye!~n",[self()]);  % NO recursive call
        _ -> loop(Val) % other messages are discarded
    end.
```

erl session

```
134> c(icounter).
{ok,icounter}
135> Icnt = icounter:start().
<0.336.0>
136> icounter:inc(Icnt).
true
137> icounter:inc(Icnt).
true
138> icounter:inc(Icnt).
true
139> icounter:inc(Icnt).
true
140> icounter:inc(Icnt).
true
141> icounter:inc(Icnt).
true
142> icounter:val(Icnt).
6
143> icounter:reset(Icnt).
true
144> icounter:val(Icnt).
0
145> icounter:stop(Icnt).
<0.336.0> says bye!
true
146> icounter:inc(Icnt).
true
147> icounter:val(Icnt).
^G
User switch command (type h for help)
 --> i

 --> c

** exception exit: killed
```

icounter.erl

```erlang
-module(icounter).
-export([start/0,loop/1,inc/1,val/1,reset/1,stop/1]).

start() ->
    spawn(icounter, loop, [0]).

loop(Val) ->
    receive
        inc -> loop(Val + 1);
        reset -> loop(0);
        {From,val} -> From ! {self(),Val}, % RECEIVE AND REPLY
                      loop(Val);
        stop -> io:format("~p says bye!~n",[self()]);
        _ -> loop(Val)
    end.

% functions over counters
inc(Counter) ->
    Counter ! inc,
    true .

val(Counter) ->
    Counter ! {self(),val}, % SEND REQUEST
    receive
        {Counter,Value} -> Value; % WAIT FOR REPLY
        _ -> true
    end.

reset(Counter) ->
    Counter ! reset,
    true .

stop(Counter) ->
    Counter ! stop,
    true .
```

erl session

alarm.erl

alarm.erl

```
1  -module(alarm).
2  -export([start/2,cancel/1,alarm/3,sleep/1,flush/0,priority_rec/0]).
3
4  start(Time, Alarm) ->
5      spawn(alarm, alarm, [self(),Time,Alarm]).
6
7  cancel(Timer) ->
8      Timer ! {self(),cancel}.
9
10 alarm(Pid, Time, Alarm) ->
11     receive
12         {Pid,cancel} -> true
13     % DO SOMETHING IF NO MESSAGE ARRIVES IN TIME
14     after Time -> Pid ! Alarm
15     % special values:
16     % infinity: timeout will never occur
17     %           useful if time is computed at runtime
18     % 0: tries all messages currently in the mailbox first
19     end.
20
21 % c(alarm).
22 % alarm:start(10000,wake_up).
23 % receive A -> A end.
24 %
25 % Al = alarm:start(30000,wake_up).
26 % alarm:cancel(Al).
```

erl session

alarm.erl

alarm.erl

```erlang
-module(alarm).
-export([start/2,cancel/1,alarm/3,sleep/1,flush/0,priority_rec/0]).

start(Time, Alarm) ->
    spawn(alarm, alarm, [self(),Time,Alarm]).

cancel(Timer) ->
    Timer ! {self(),cancel}.

alarm(Pid, Time, Alarm) ->
    receive
        {Pid,cancel} -> true
    % DO SOMETHING IF NO MESSAGE ARRIVES IN TIME
    after Time -> Pid ! Alarm
    % special values:
    % infinity: timeout will never occur
    %           useful if time is computed at runtime
    % 0: tries all messages currently in the mailbox first
    end.

% c(alarm).
% alarm:start(10000,wake_up).
% receive A -> A end.
%
% Al = alarm:start(30000,wake_up).
% alarm:cancel(Al).
```

```
148> c(alarm).
{ok,alarm}
149> alarm:start(10000,wake_up).
<0.356.0>
150> receive A -> A end.
wake_up
```

erl session

```
28  %% EXAMPLES with timeouts
29
30  sleep(Time) ->
31      receive
32      after Time -> true
33      end.
34  % alarm:sleep(5000).
35
36
37
38  flush() ->
39      receive
40          Any -> io:format("flush ~p~n",[Any]),
41                 flush()
42      after 0 -> true
43      end.
44  % self() ! one.
45  % self() ! two.
46  % self() ! three.
47  % self() ! four.
48  % alarm:flush().
```

erl session

```
151> self() ! {good,goal}.
{good,goal}
152> self() ! {good,win}.
{good,win}
153> self() ! {bad,loose}.
{bad,loose}
154> self() ! {good,baby_born}.
{good,baby_born}
155> alarm:priority_rec().
loose
156> alarm:priority_rec().
goal
157> alarm:priority_rec().
win
158> alarm:priority_rec().
baby_born
159> alarm:priority_rec().
^G
User switch command (type h for help)
 --> i

 --> c
** exception exit: killed
160> halt().
```

```
50  priority_rec() ->
51      receive
52          {bad,News} -> News
53      after 0 ->
54          receive
55              {good,News} -> News
56          end
57      end.
```