Memory Model

CS 113: Introduction to C

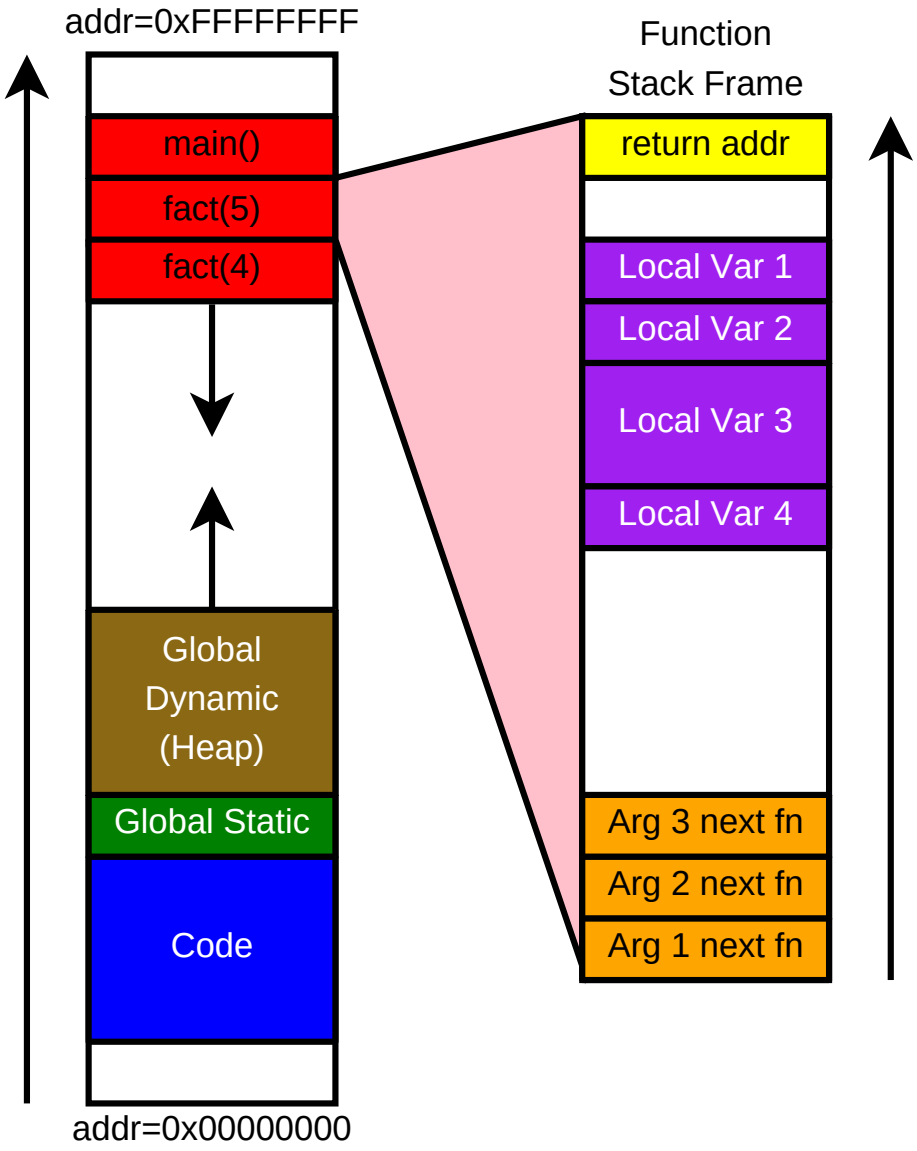
Instructor: Saikat Guha

Cornell University

Spring 2007, Lecture 4

Memory

- Program code
- Function variables
  - Arguments
  - Local variables
  - Return location
- Global Variables
  - Statically Allocated
  - Dynamically Allocated



The Stack

Stores

- Function local variables
- Temporary variables
- Arguments for next function call
- Where to return when function ends

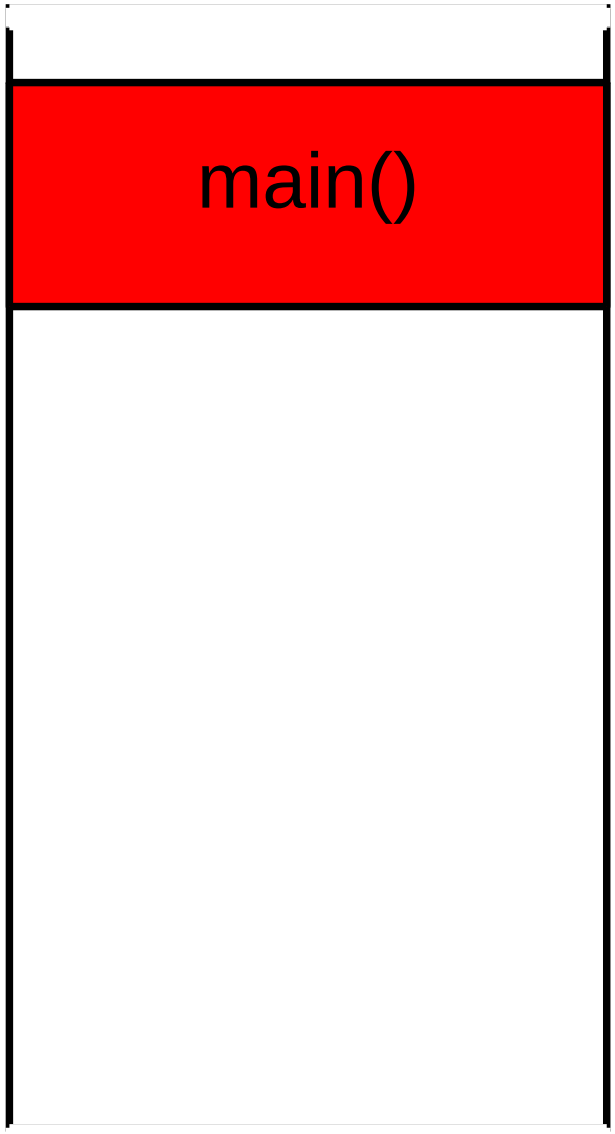
The Stack

Managed by compiler

- One stack frame each time function called
- Created when function called
- Stacked on top (under) one another
- Destroyed at function exit

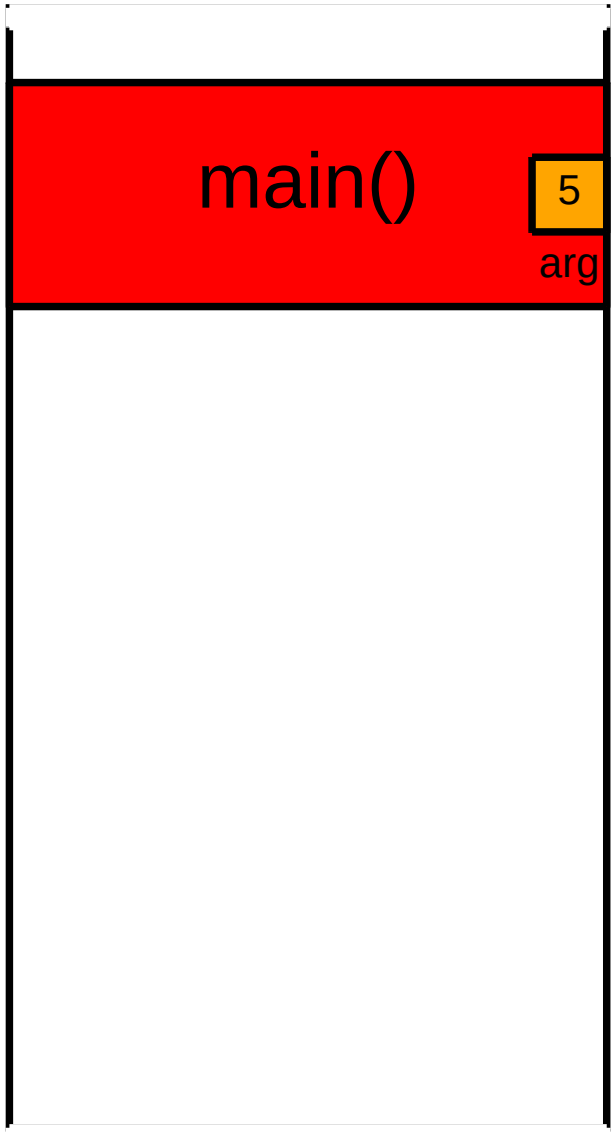
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



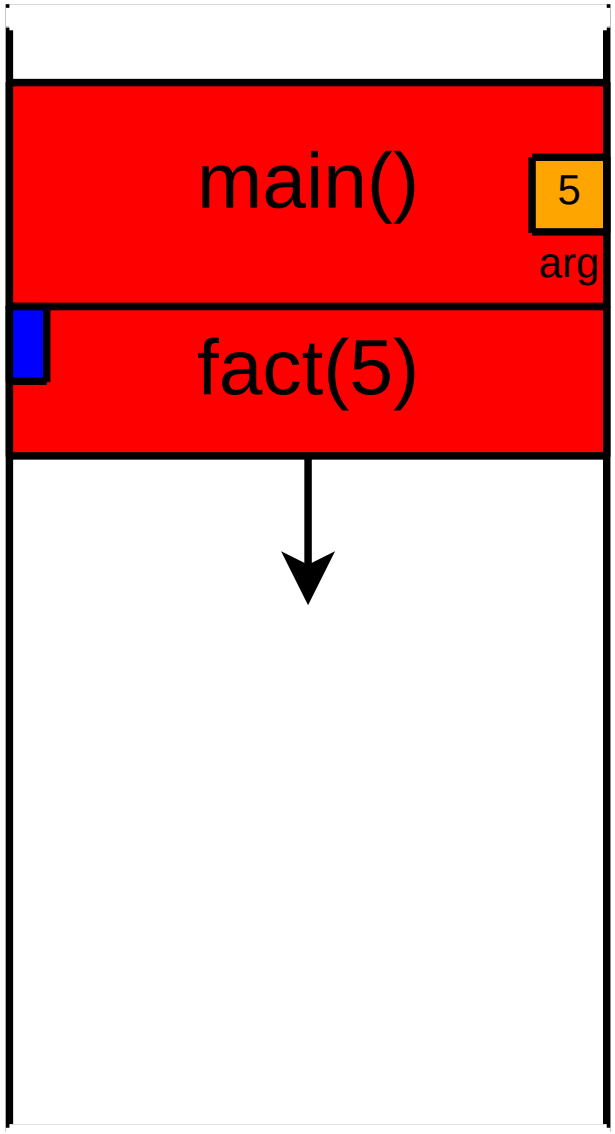
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



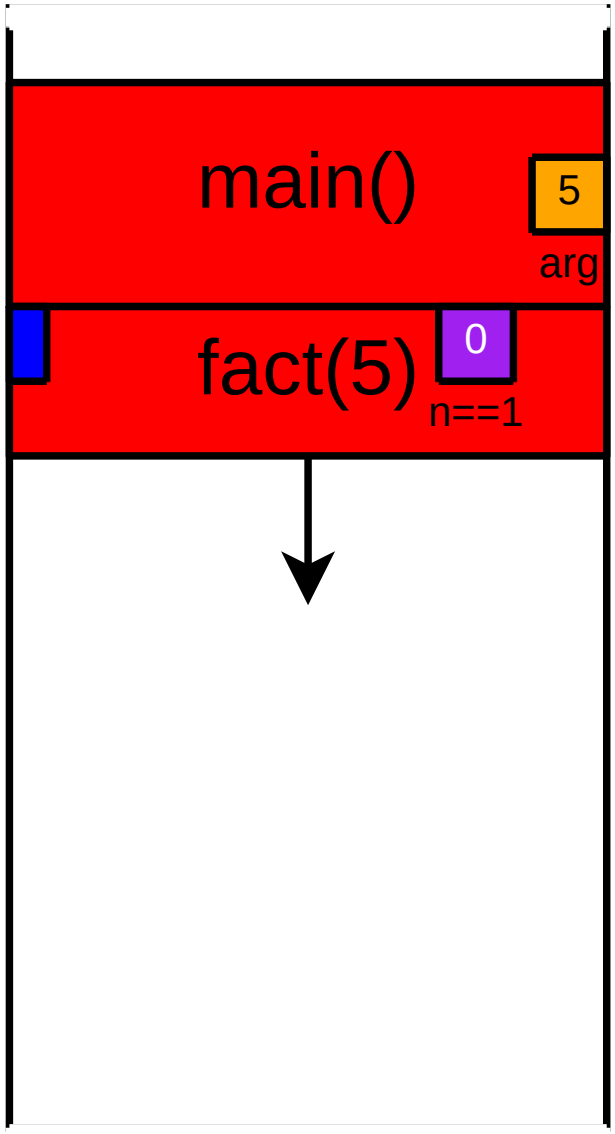
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



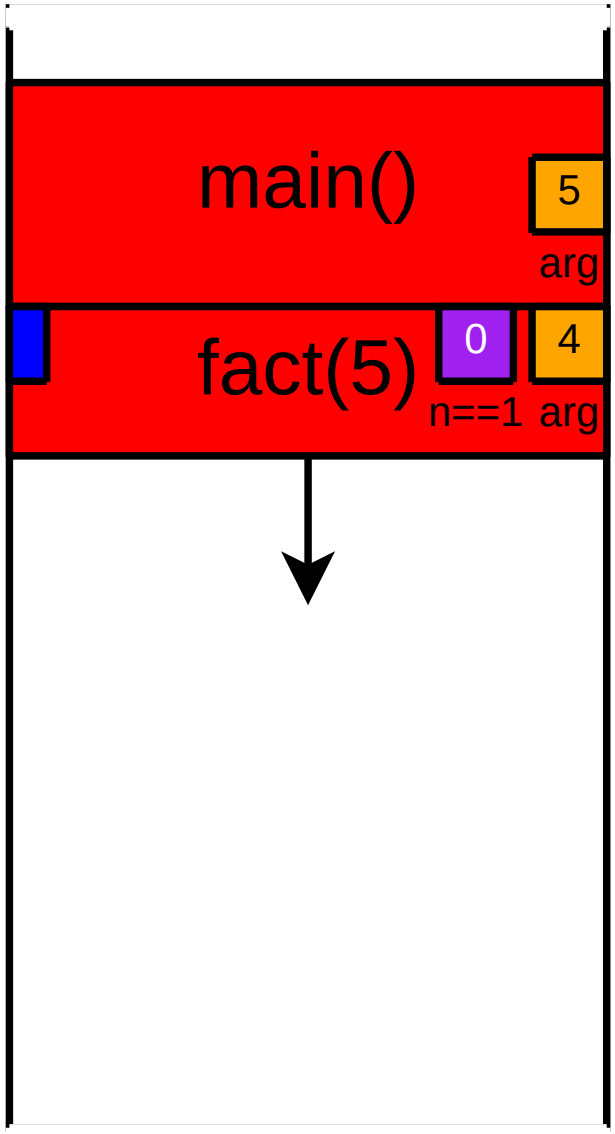
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



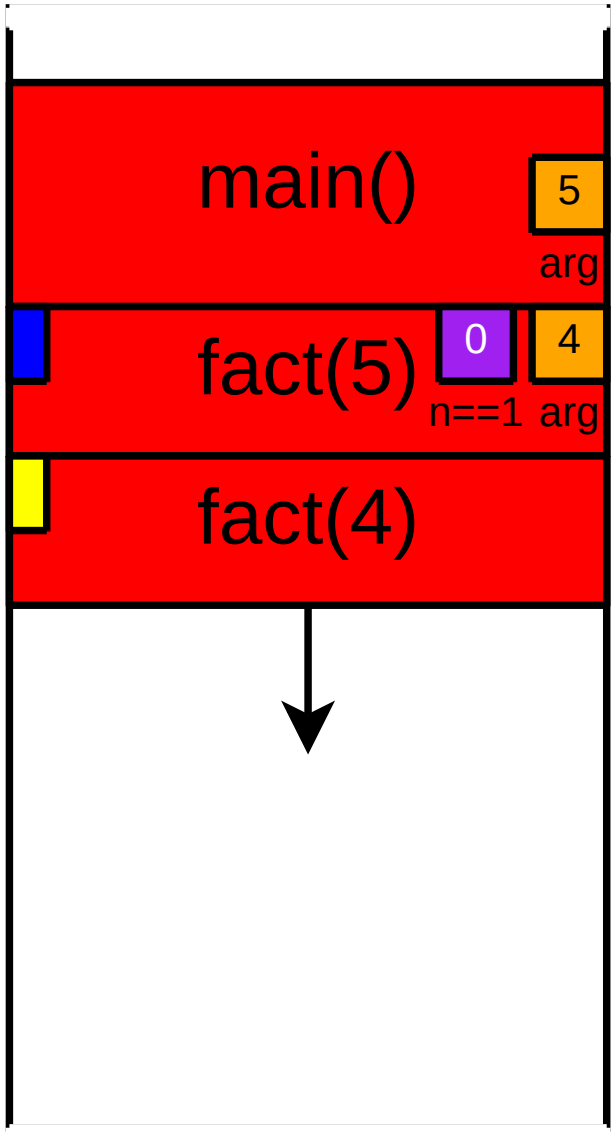
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



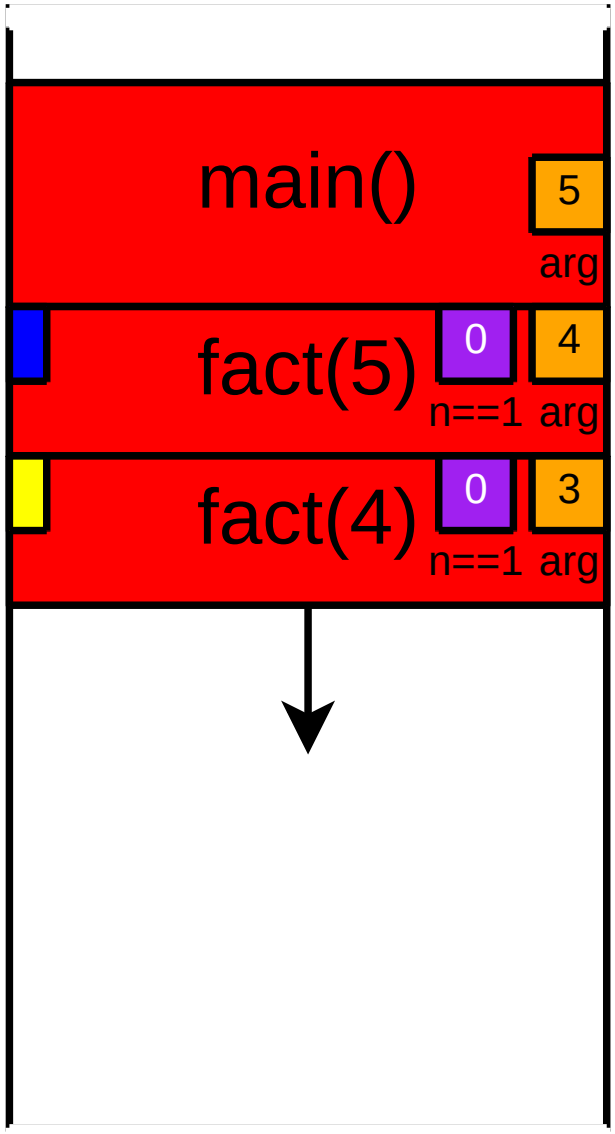
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



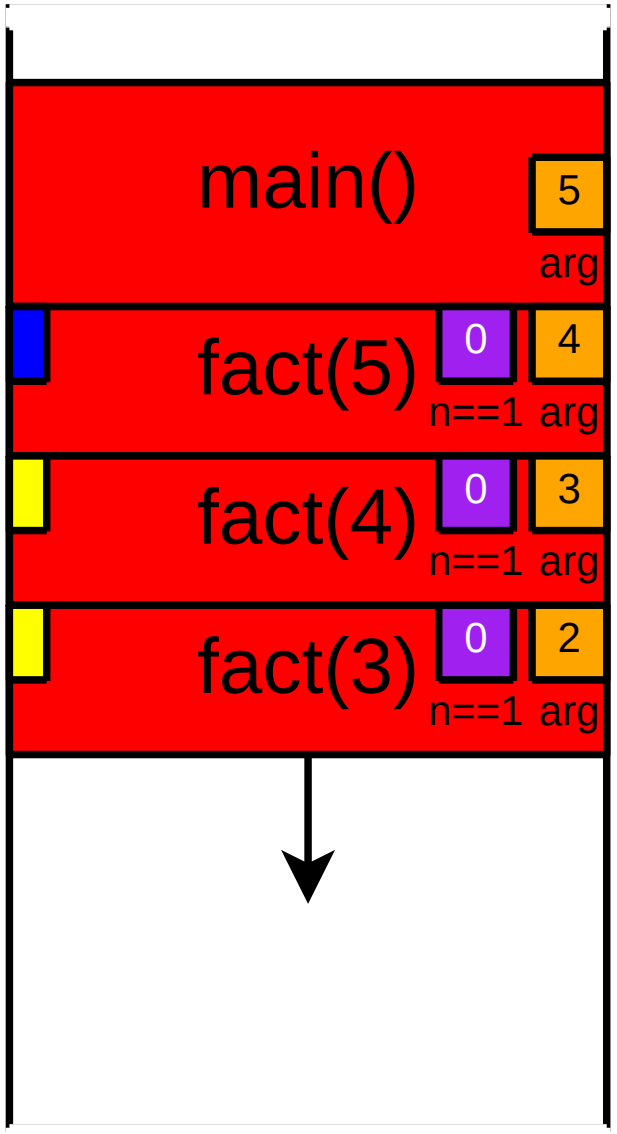
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



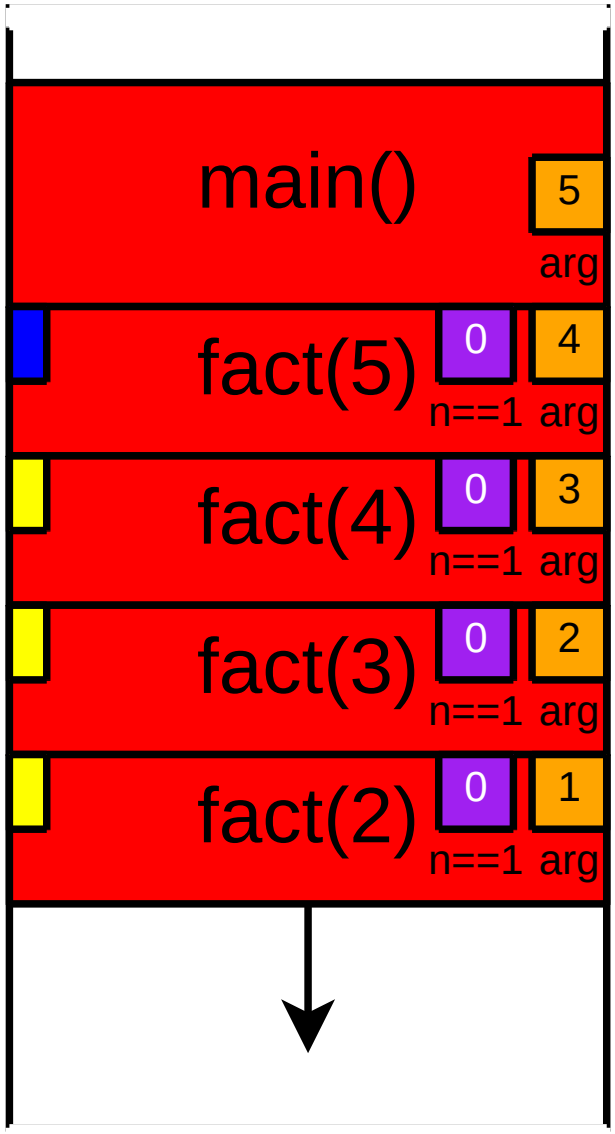
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



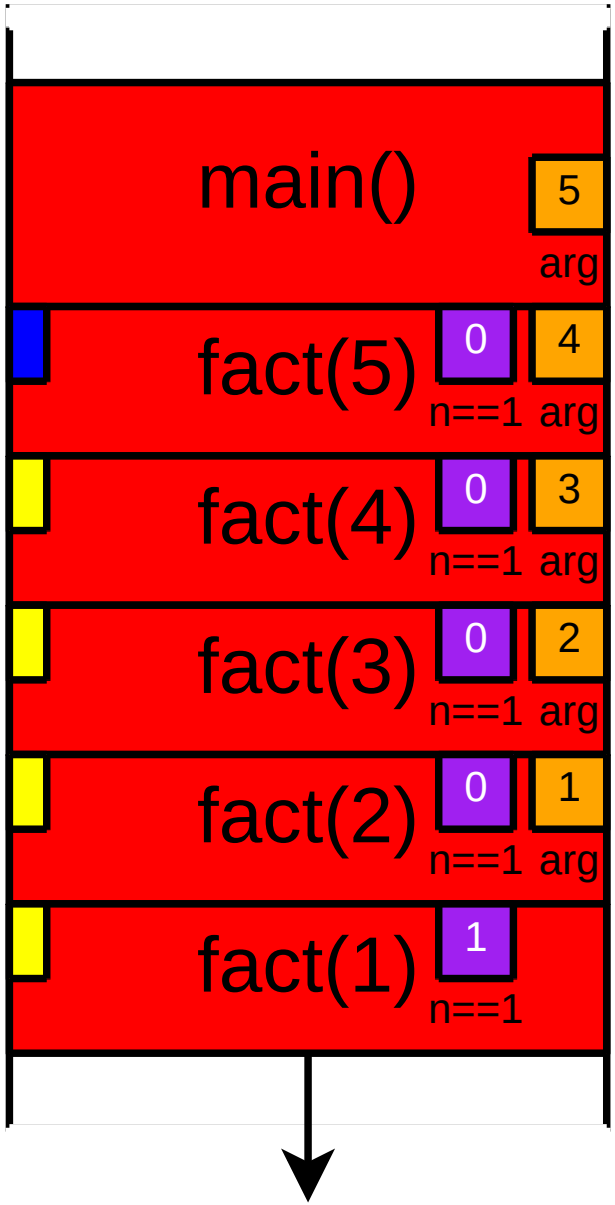
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



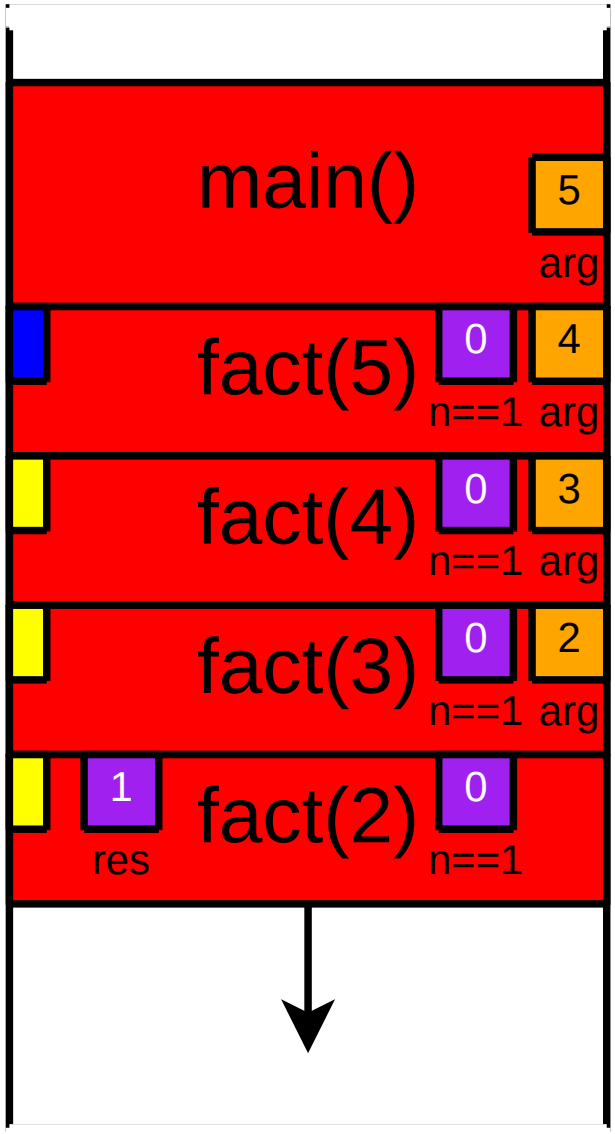
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



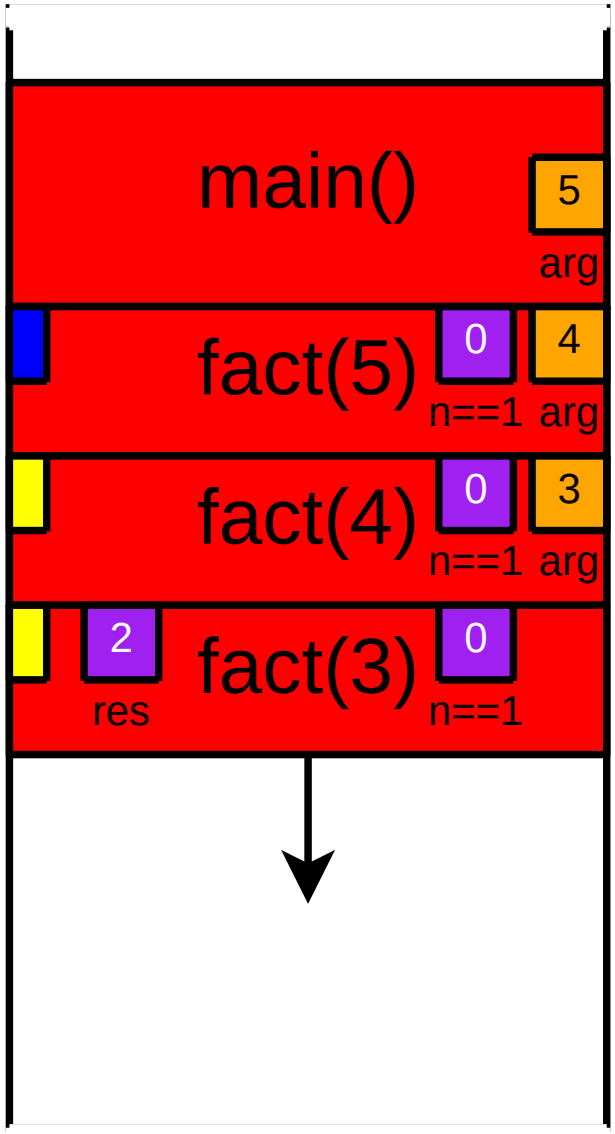
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



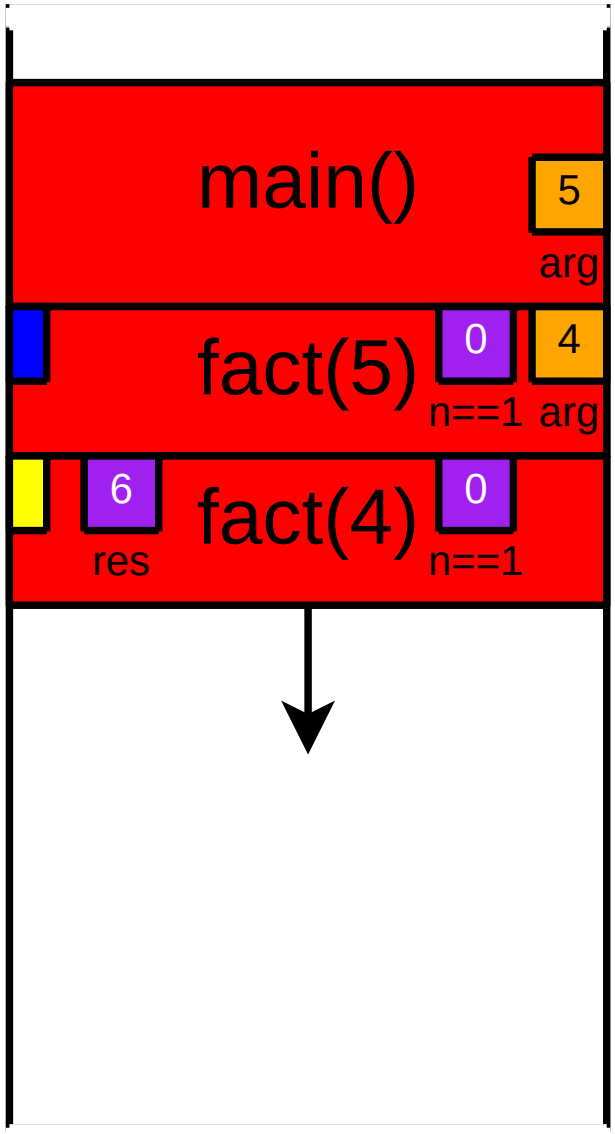
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



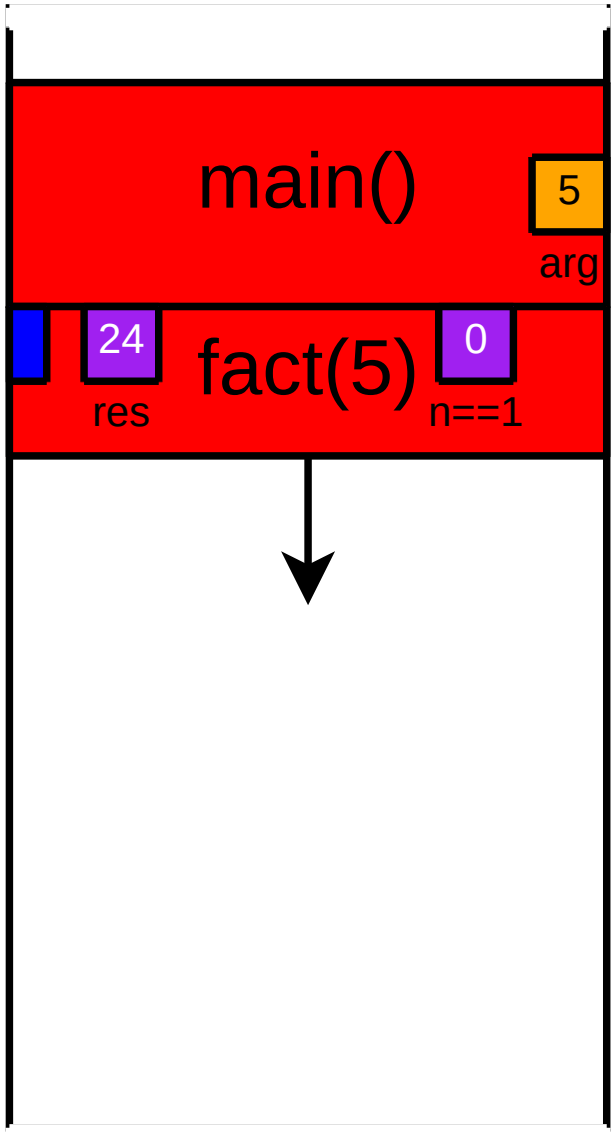
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



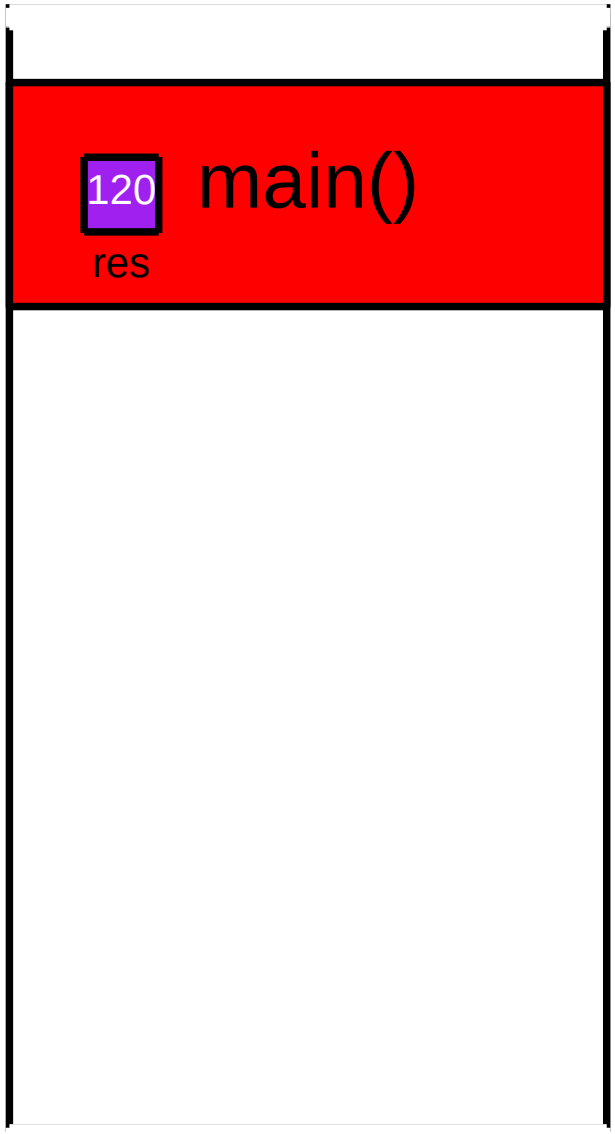
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



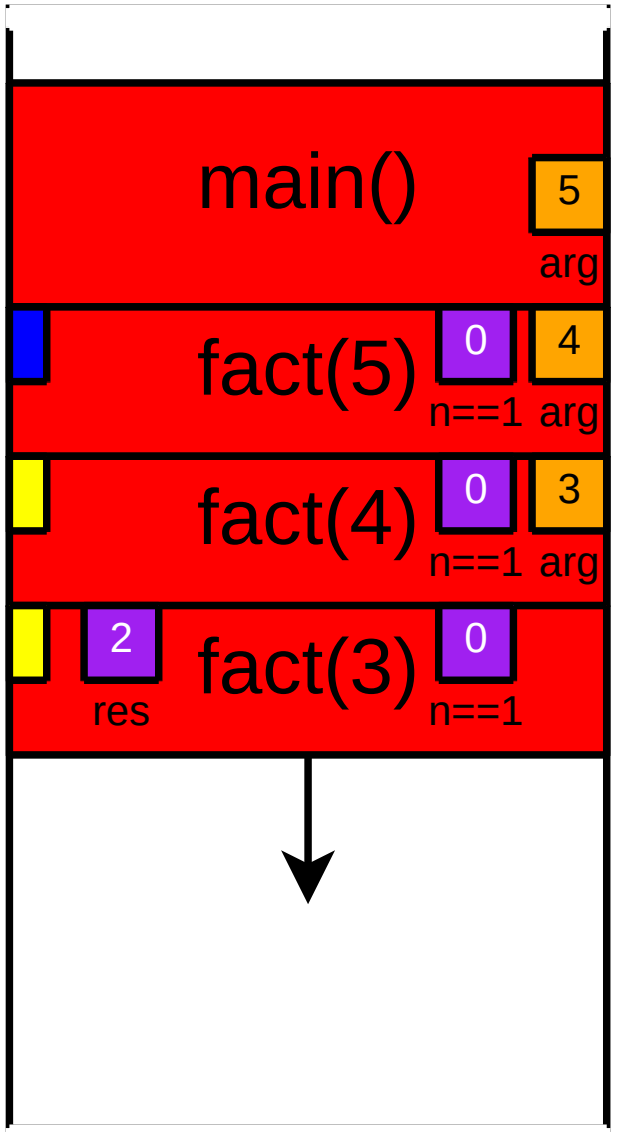
The Stack

```
int fact(int n) {
    int res;
    if (n == 1)
        return 1;
    res = fact(n-1);
    return n * res;
}

int main() {
    int res = fact(5);
    return 0;
}
```



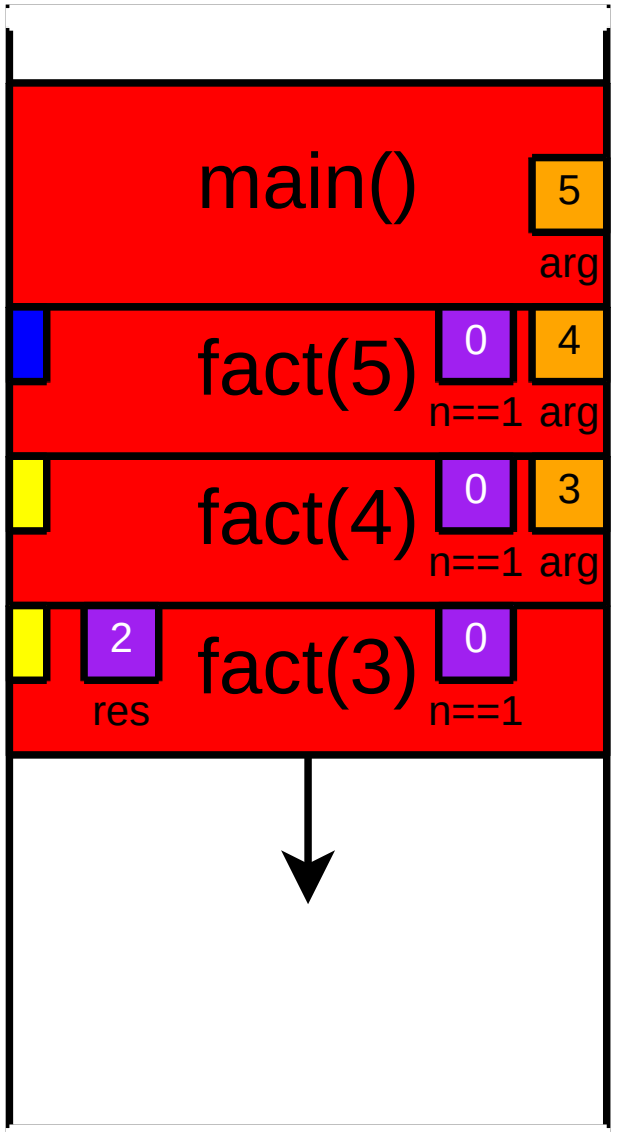
Stack games

- Locate the stack
- Find the direction of stack growth
- Finding size of stack frame



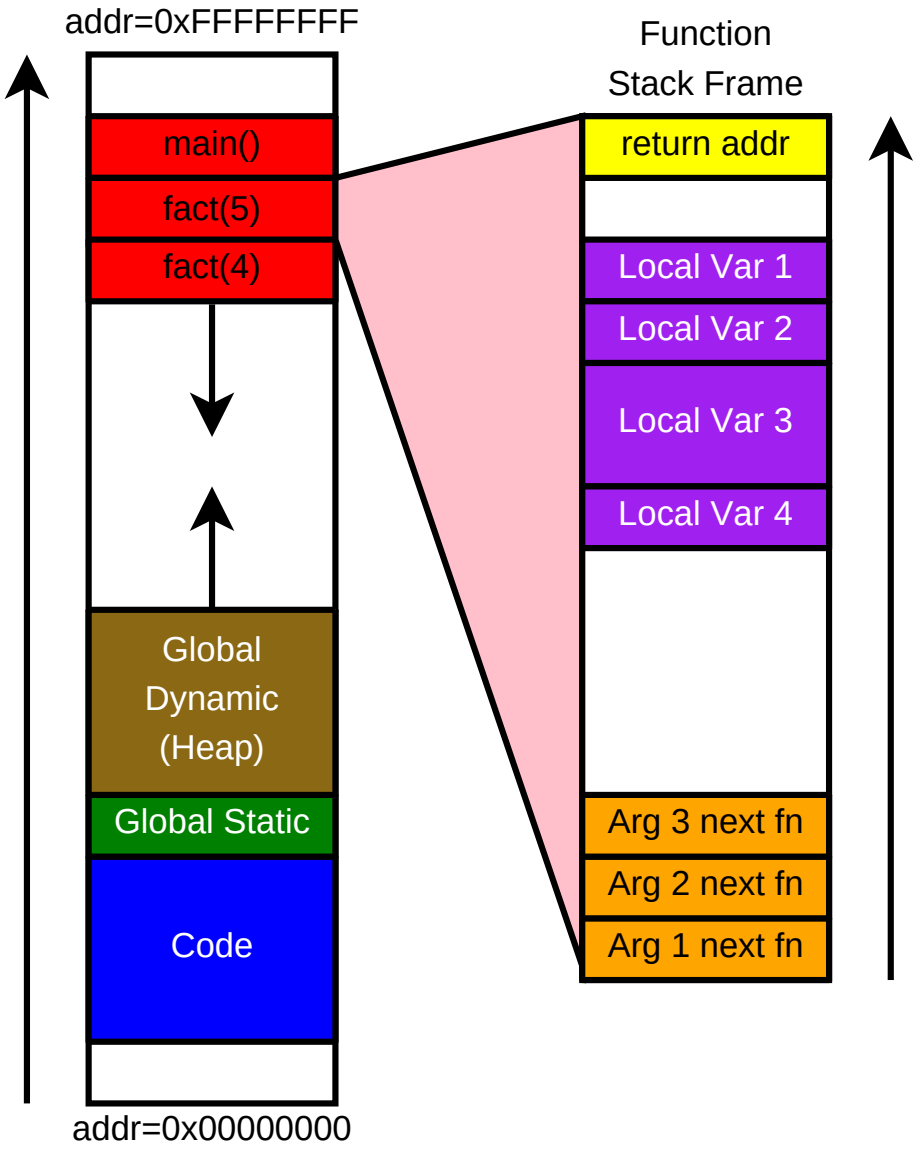
What can go wrong

- Run out of stack space
- Unintentionally change values on the stack
  - In some other function's frame
  - Even return address from function
- Access memory even after frame is deallocated



Memory Recap

- Program code
- Function variables
  - Arguments
  - Local variables
  - Return location
- Global Variables
  - Statically Allocated
  - Dynamically Allocated



Heap

Heap

Needed for long-term storage that needs to persist across multiple function calls.

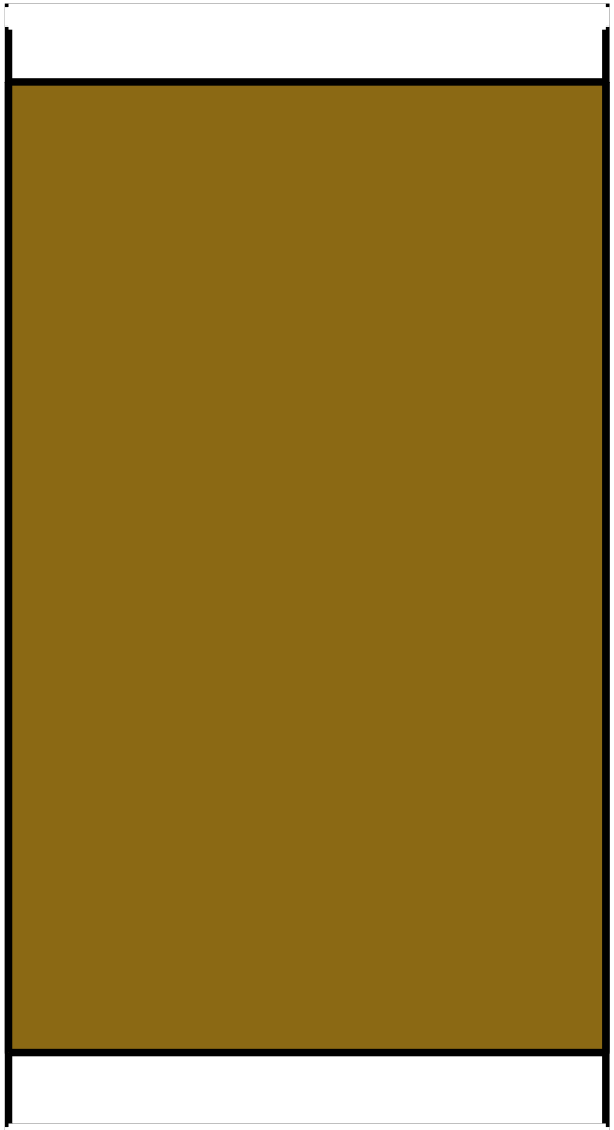
Managed by programmer

- Created by `ptr = malloc(size)`
- Destroyed by `free(ptr)`

MUST check the return value from `malloc`
MUST explicitly `free` memory when no longer in use

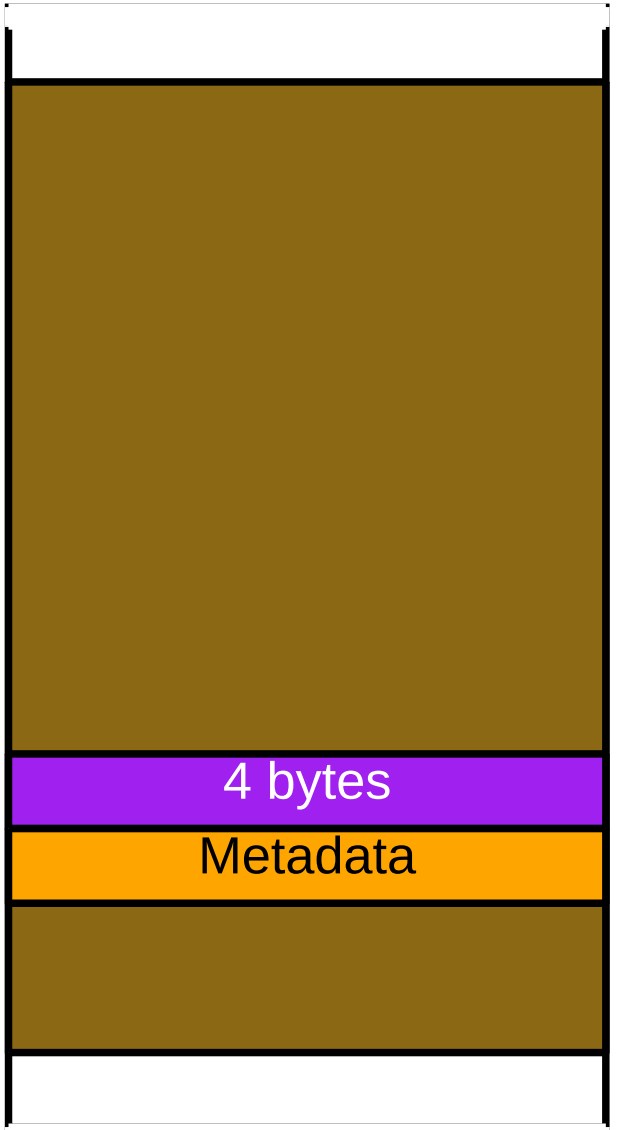
The Heap

```
int main() {
  int *p, *q, *r;

  p = (int *)malloc(sizeof(int));
  q = (int *)malloc(
      sizeof(int) * 10);
  r = (int *)malloc(sizeof(int));

  if (p == NULL || !q || !r) {
    ...  do cleanup ...
    return 1;
  }

  free(p);
  ...  do other stuff ...
```



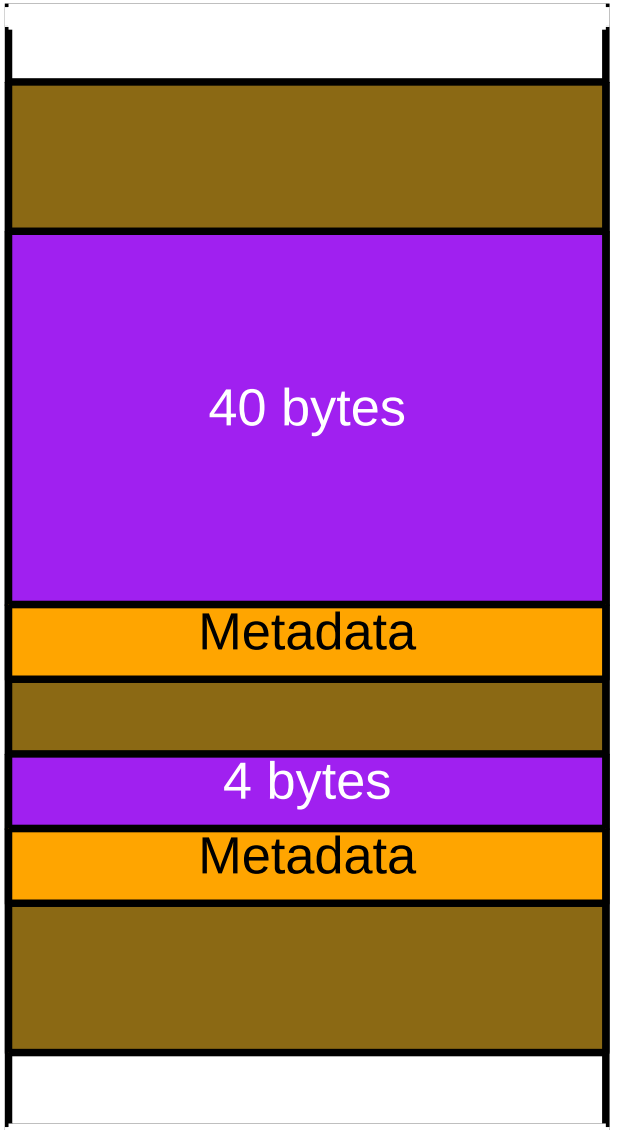
The Heap

```
int main() {
  int *p, *q, *r;

  p = (int *)malloc(sizeof(int));
  q = (int *)malloc(
      sizeof(int) * 10);
  r = (int *)malloc(sizeof(int));

  if (p == NULL || !q || !r) {
    ...  do cleanup ...
    return 1;
  }

  free(p);
  ...  do other stuff ...
```



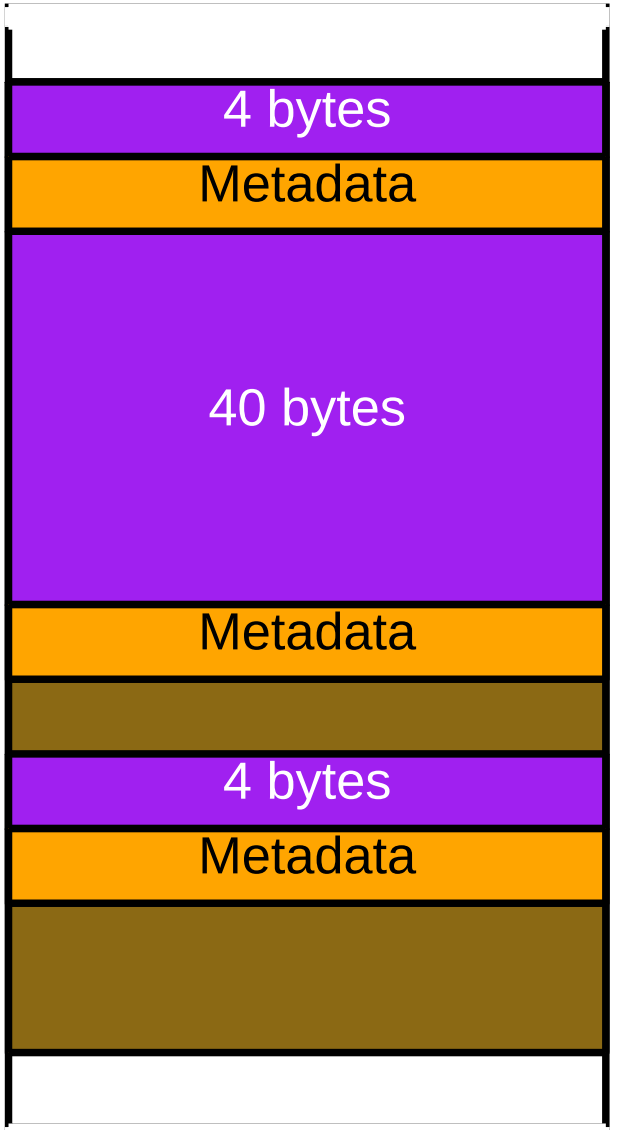
The Heap

```
int main() {
  int *p, *q, *r;

  p = (int *)malloc(sizeof(int));
  q = (int *)malloc(
      sizeof(int) * 10);
  r = (int *)malloc(sizeof(int));

  if (p == NULL || !q || !r) {
    ...  do cleanup ...
    return 1;
  }

  free(p);
  ...  do other stuff ...
```



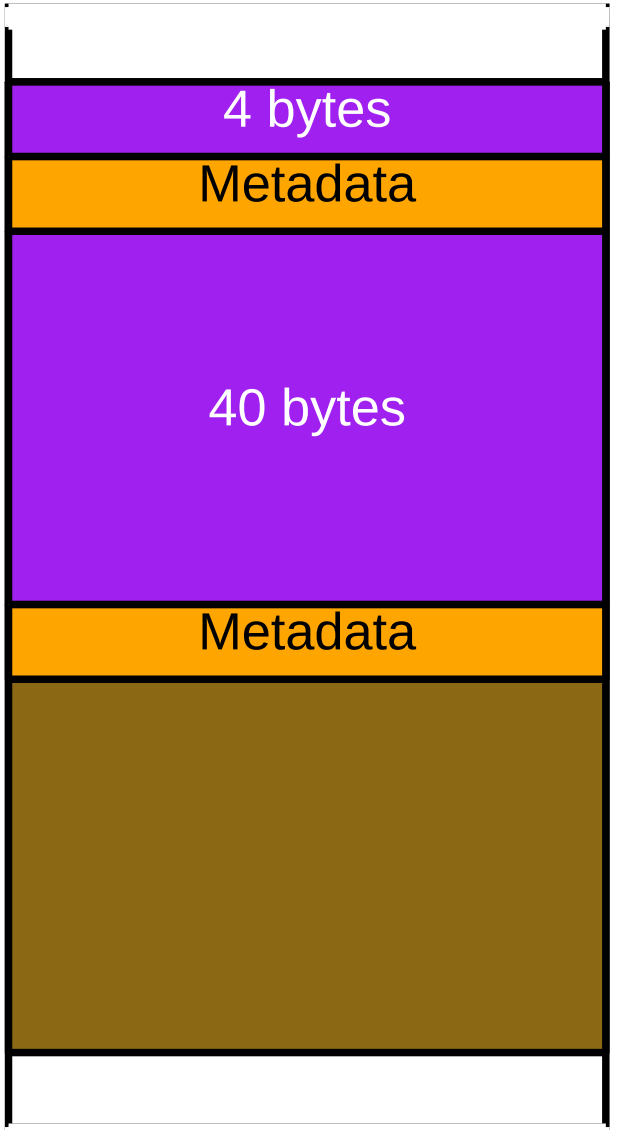
The Heap

```
int main() {
  int *p, *q, *r;

  p = (int *)malloc(sizeof(int));
  q = (int *)malloc(
      sizeof(int) * 10);
  r = (int *)malloc(sizeof(int));

  if (p == NULL || !q || !r) {
    ...  do cleanup ...
    return 1;
  }

  free(p);
  ...  do other stuff ...
```



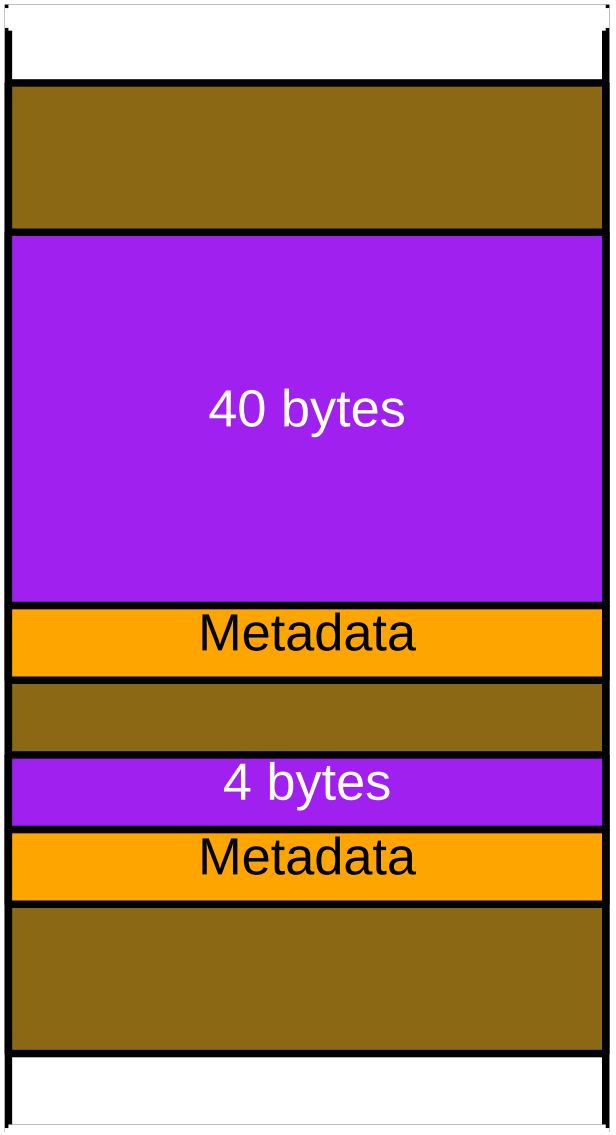
The Heap

```
int main() {
  int *p, *q, *r;

  p = (int *)malloc(sizeof(int));
  q = (int *)malloc(
      sizeof(int) * 10);
  r = (int *)malloc(sizeof(int));

  if (p == NULL || !q || !r) {
    ...  do cleanup ...
    return 1;
  }

  free(p);
  ...  do other stuff ...
```



Heap games

- Locate the heap
- How freespace is managed
- Find how memory is allocated
  - How is fragmentation avoided



What can go wrong

- Run out of heap space `malloc` returns 0
- Unintentionally change other heap data
  - Or clobber heap metadata
- Access memory even `free`'d
- `free` memory twice
- Create a memory leak