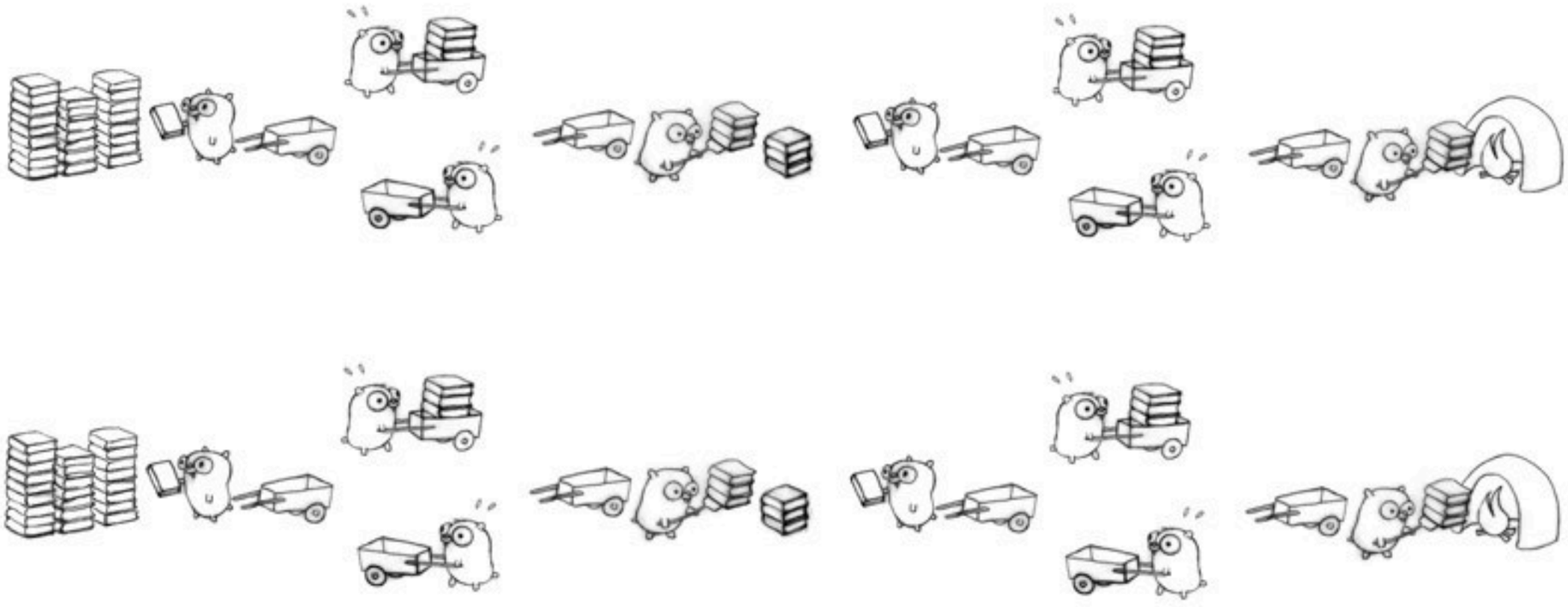


Go Routine
Concurrency and Parallelism

Jin Hyun Kim

Fall, 2019

Today

- Golang routine and channel

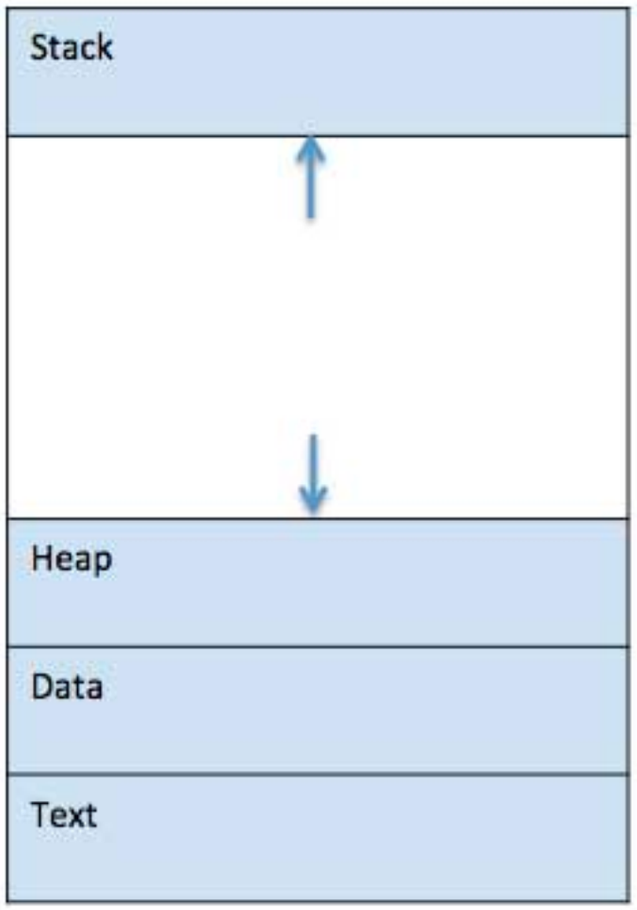
Concurrency 동시성

- Process 프로세스: CPU의 스케줄링 단위, 명령어, 사용자 데이터, 시스템 영역, 실행 과정에 수집한 다양한 종류의 리소스로 구성된 실행단위

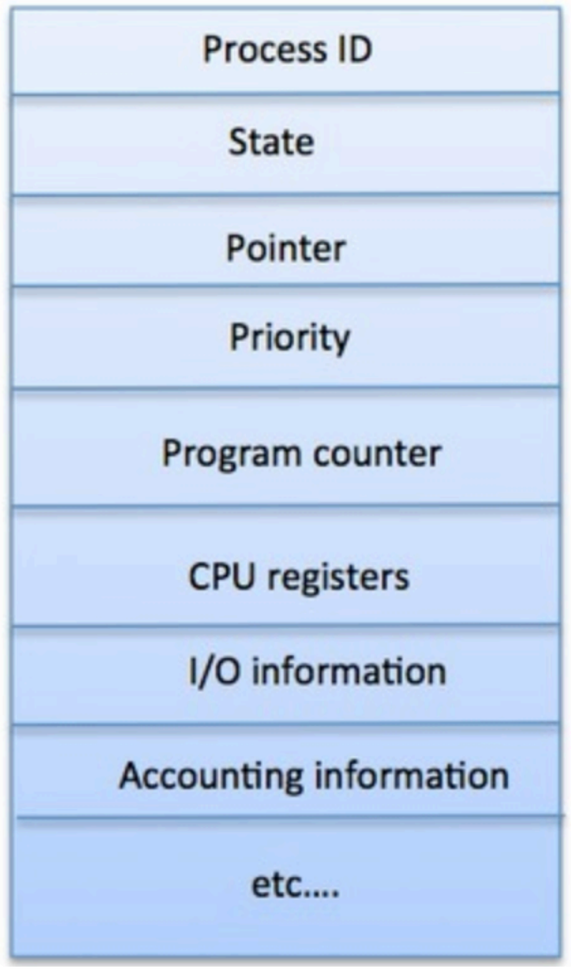
- 프로그램: 프로세스의 명령어와 데이터를 담은 파일

- Thread 쓰레드: 프로세스에 의한 보다 작은 실행단위, 독립적인 제어 흐름 및 **스택**을 갖는다.

Process

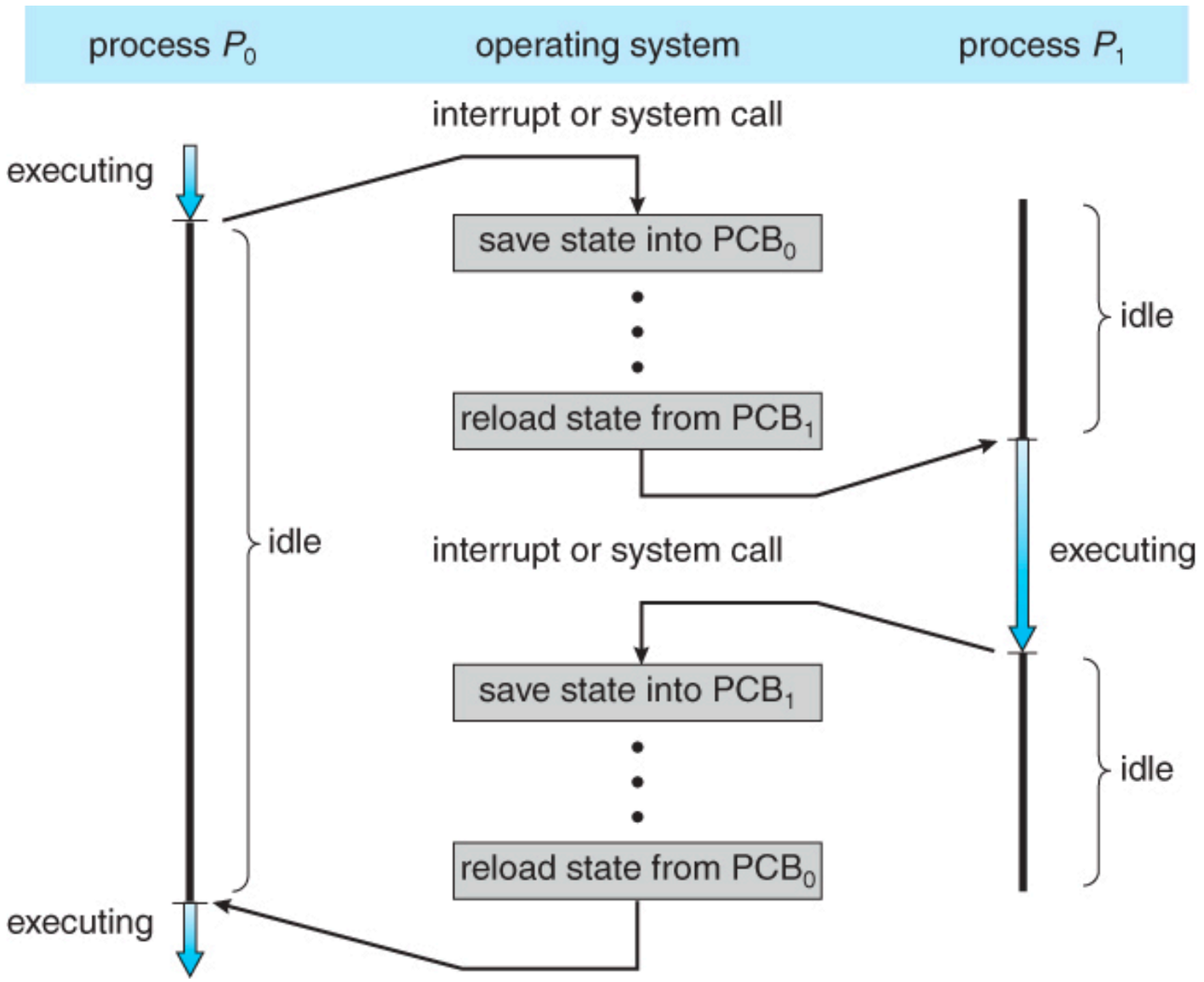


Program in Memory (Process)

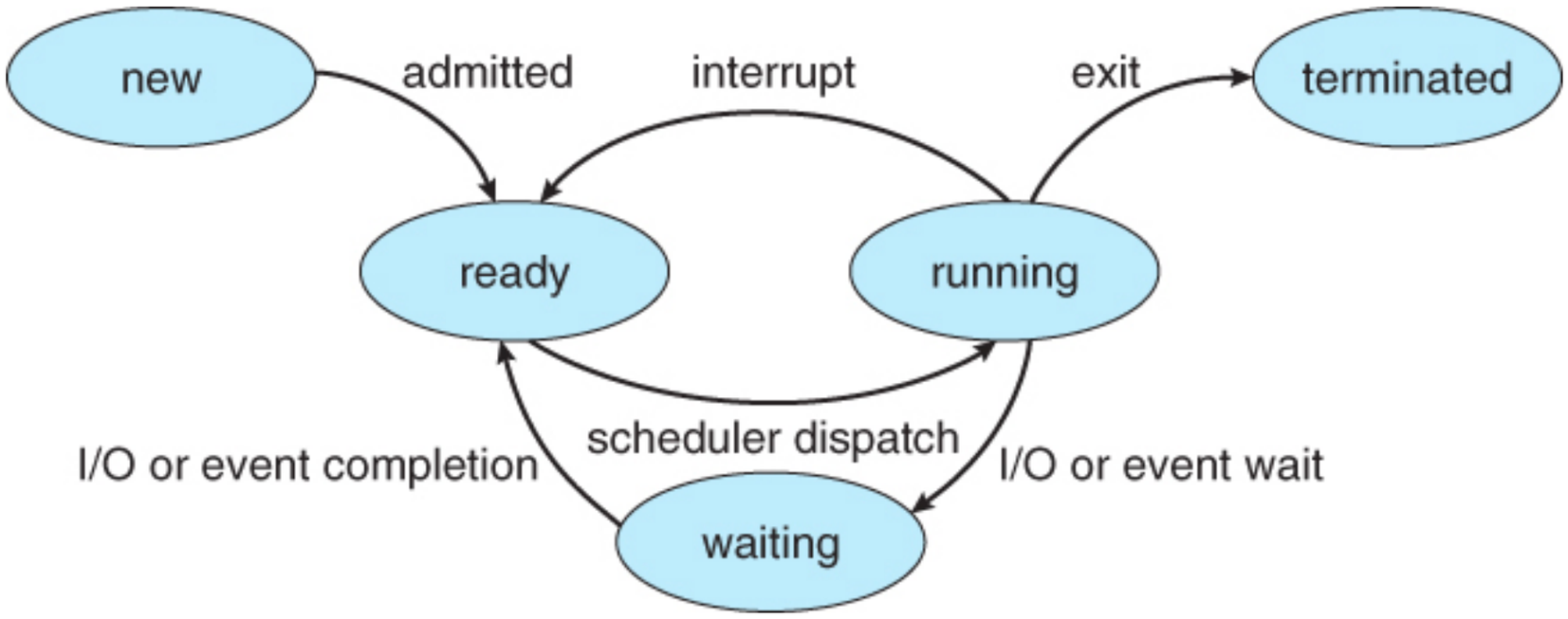


Program Control Block (PCB)

Process Context Switch
프로세스의 문맥전환

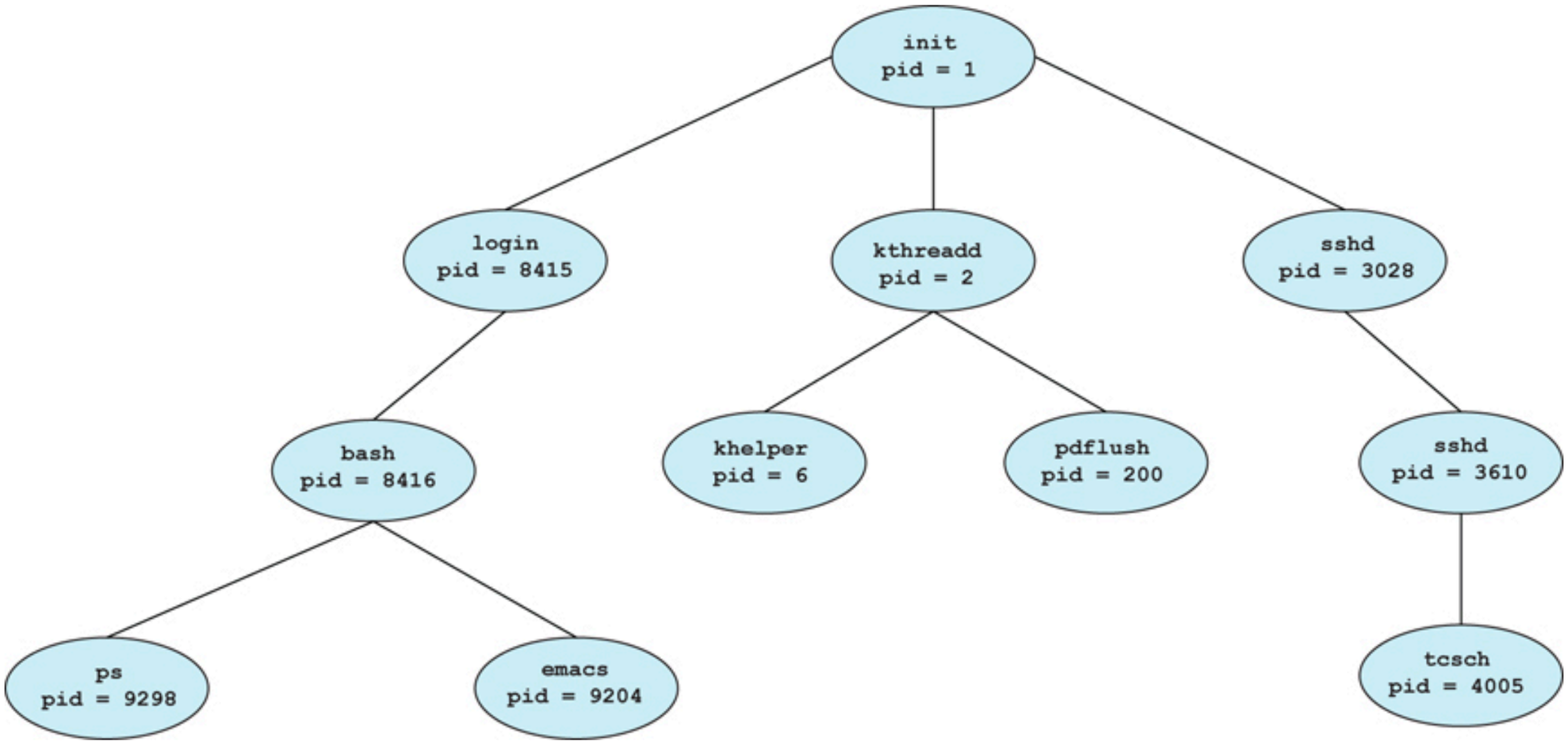


Process

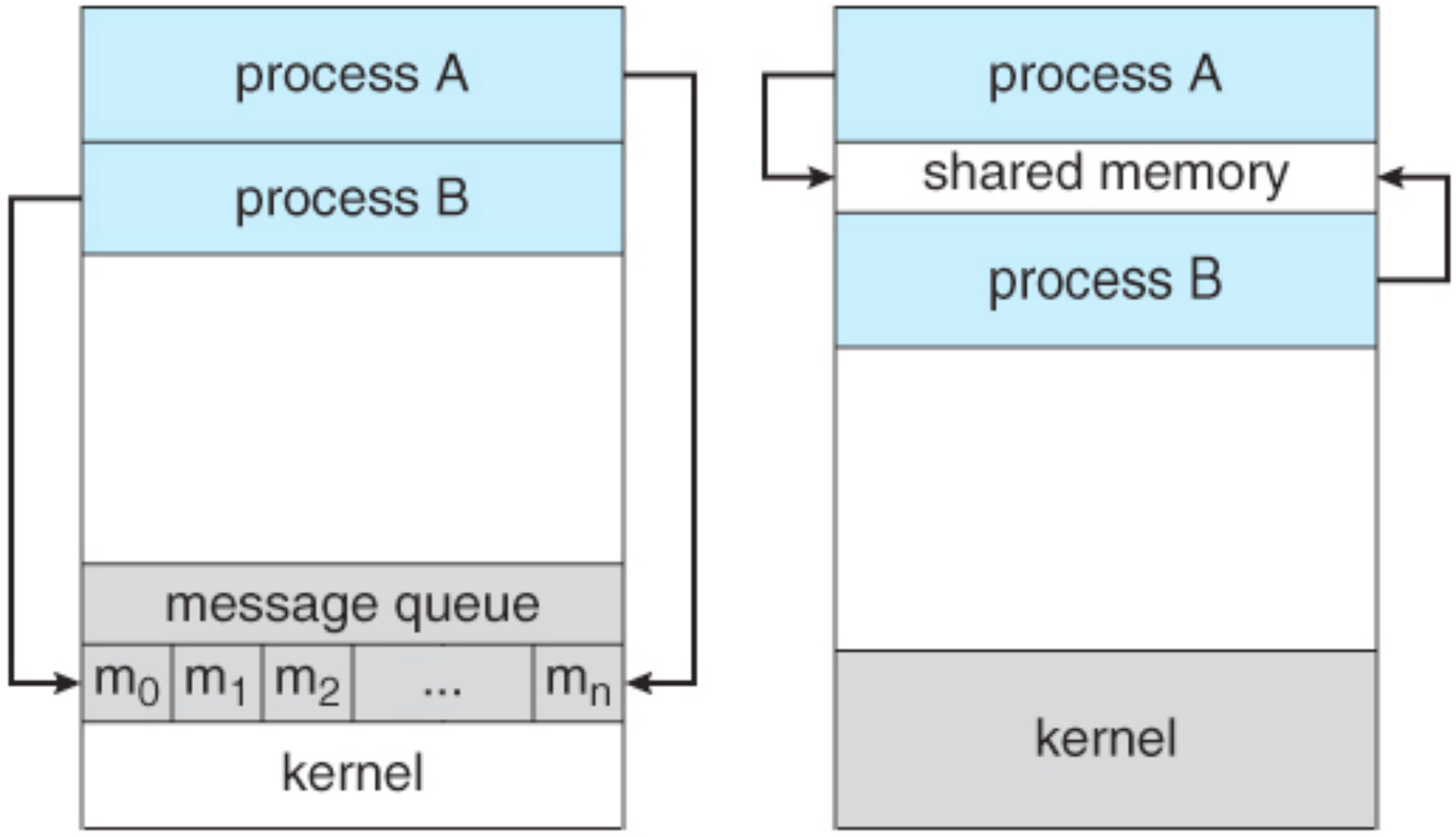


프로세스의 상태 변화

Proces in OS


init
pid = 1
login
pid = 8415
kthreadd
pid = 2
sshd
pid = 3028
bash
pid = 8416
khelper
pid = 6
pdflush
pid = 200
sshd
pid = 3610
ps
pid = 9298
emacs
pid = 9204
tcsch
pid = 4005

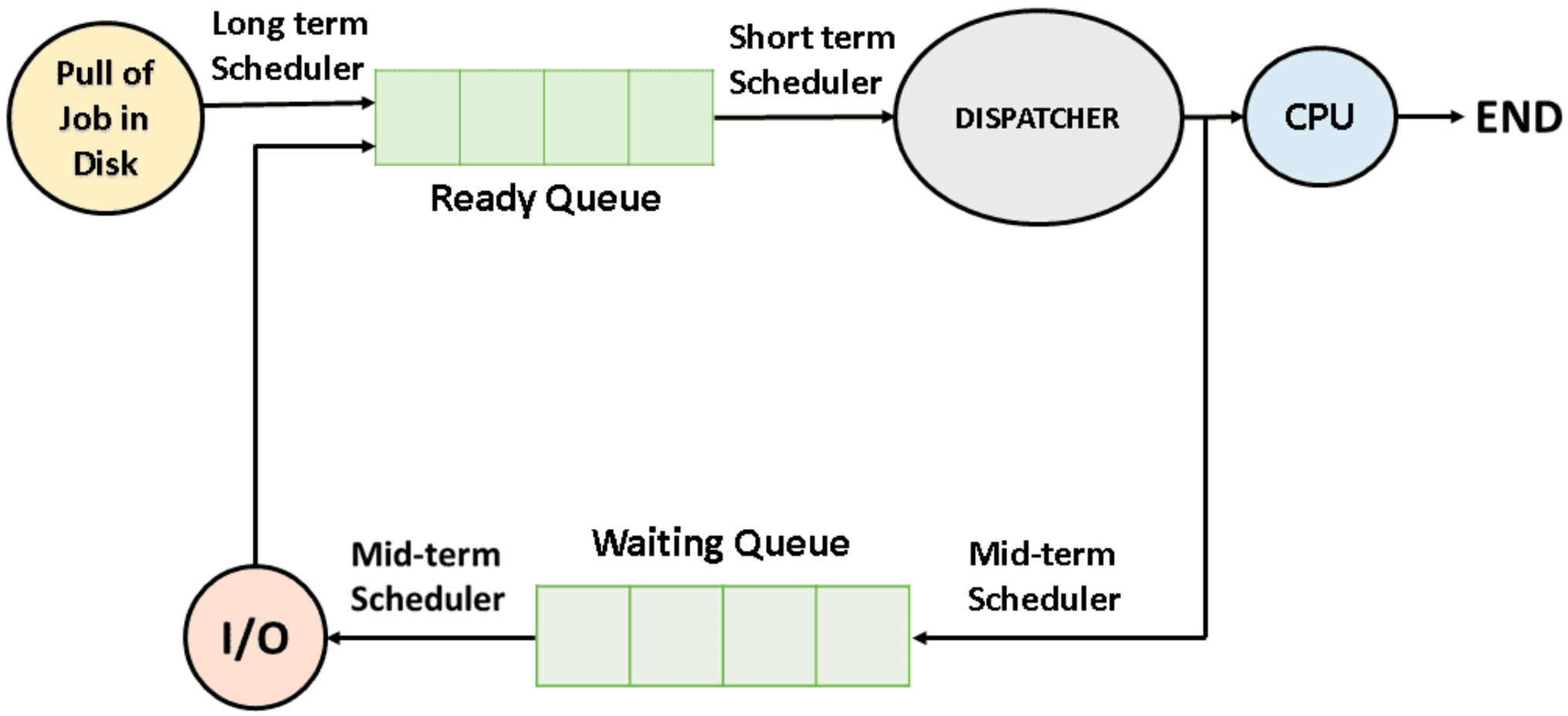
Inter-Proces Comm. (IPC)



(a) Message Passing

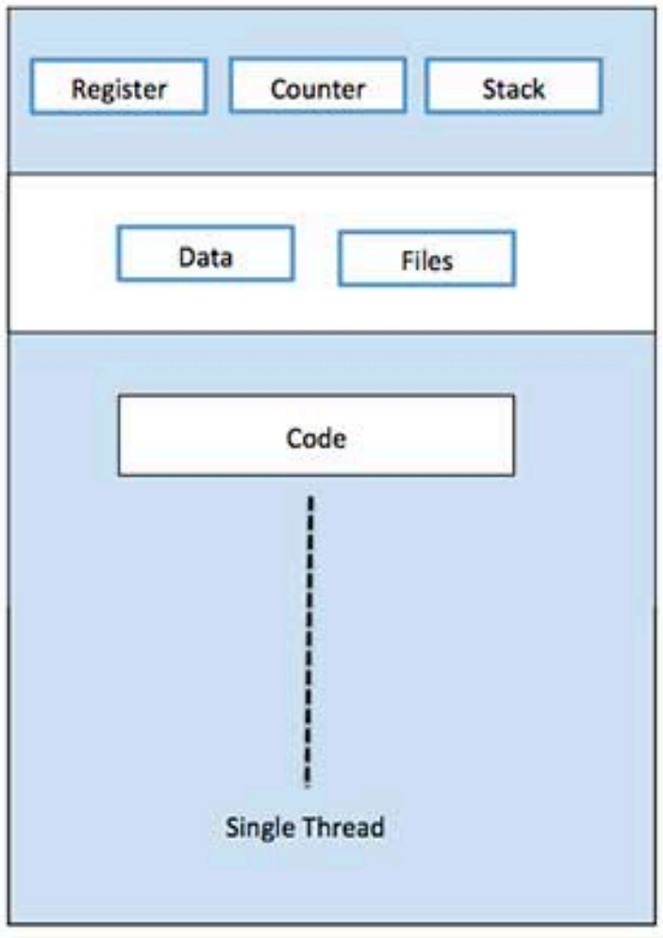
(b) Shared Memory

Process Scheduling

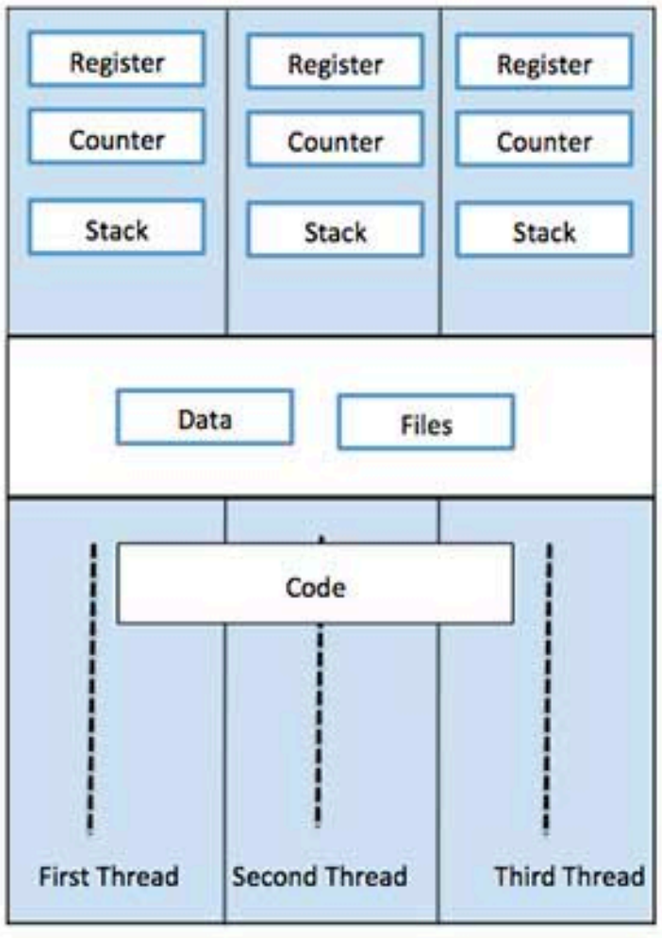


Thread

- A basic unit of CPU utilization, consisting of a program counter, a stack, and a set of registers, (and a thread ID.)



Single Process P with single thread



Single Process P with three threads

Thread

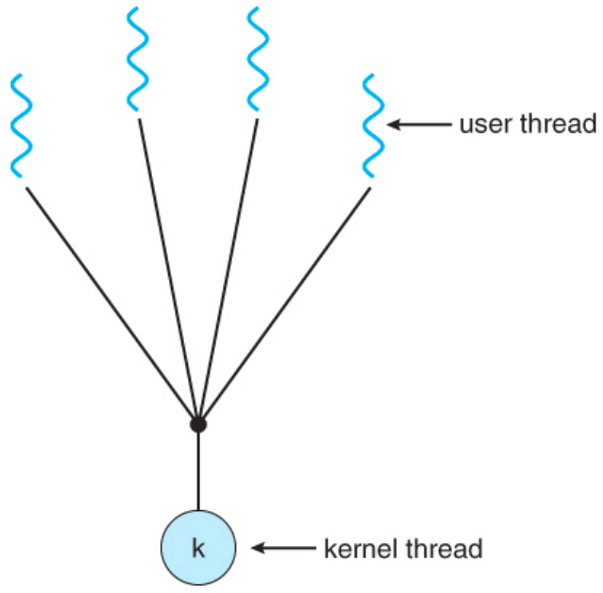
- For example in a word processor, a background thread may check spelling and grammar while a foreground thread processes user input (keystrokes), while yet a third thread loads images from the hard drive, and a fourth does periodic automatic backups of the file being edited.

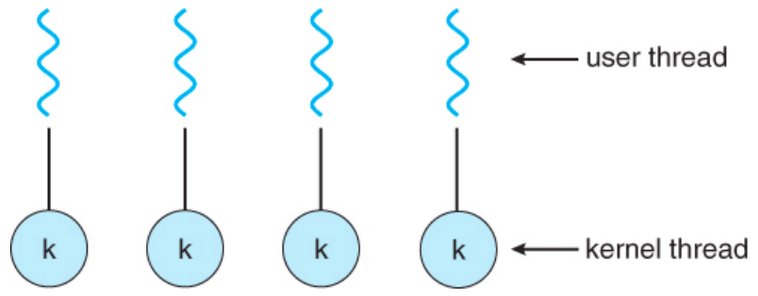
- Another example is a web server - Multiple threads allow for multiple requests to be satisfied simultaneously, without having to service requests sequentially or to fork off separate processes for every incoming request.

Thread Execution
쓰레드의 실행

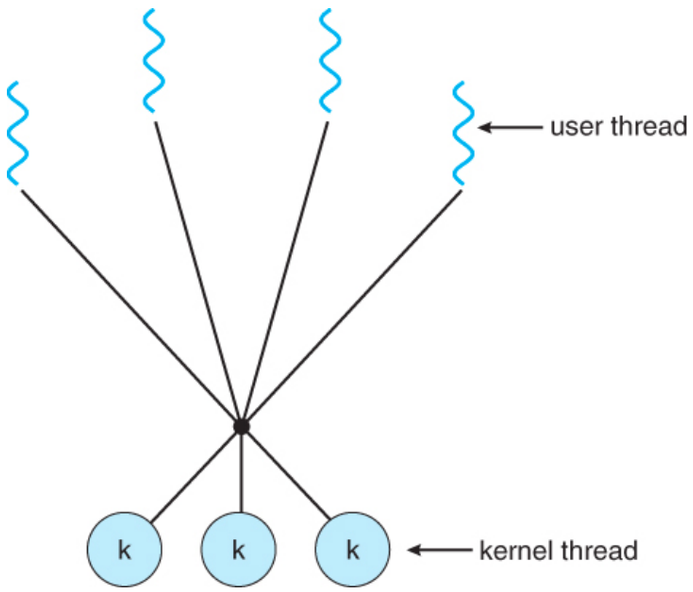
- User Level Threads – User managed threads.

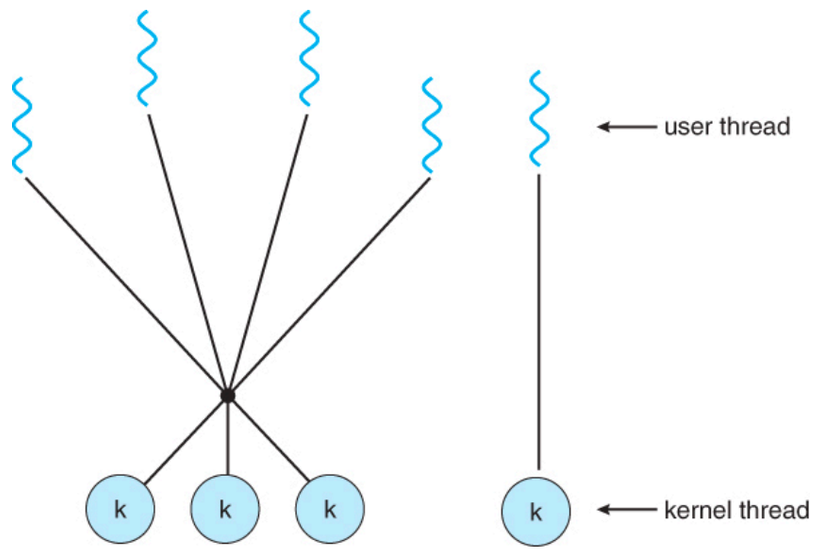
- Kernel Level Threads – Operating System managed threads acting on kernel, an operating system core.





Thread Execution
쓰레드의 실행





Process vs Thread

S.N.	Process	Thread
1	Process is heavy weight or resource intensive.	Thread is light weight, taking lesser resources than a process.
2	Process switching needs interaction with operating system.	Thread switching does not need to interact with operating system.
3	In multiple processing environments, each process executes the same code but has its own memory and file resources.	All threads can share same set of open files, child processes.
4	If one process is blocked, then no other process can execute until the first process is unblocked.	While one thread is blocked and waiting, a second thread in the same task can run.
5	Multiple processes without using threads use more resources.	Multiple threaded processes use fewer resources.
6	In multiple processes each process operates independently of the others.	One thread can read, write or change another thread's data.

Routine in Go (Goroutine)

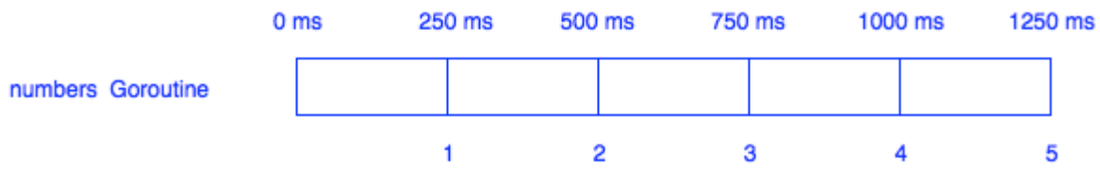
- Goroutines are functions or methods that run concurrently with other functions or methods.
- Can be thought of as light weight threads.
- The cost of creating a Goroutine is tiny when compared to a thread.

Goroutine Example

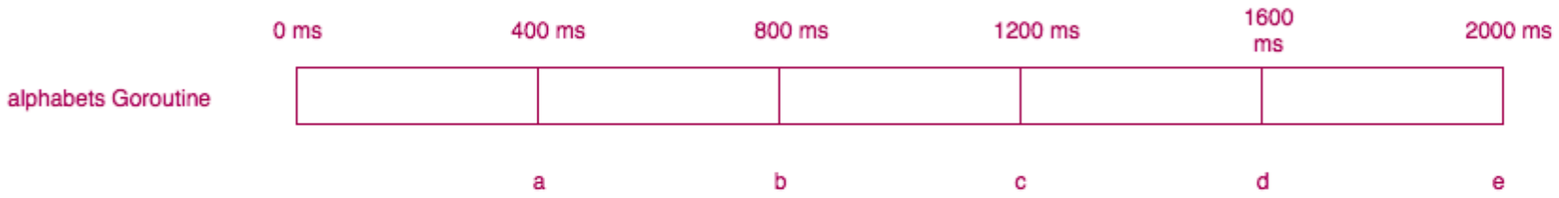
```go
package main

import (
    "fmt"
    "time"
)

func numbers() {
    for i := 1; i <= 5; i++ {
        time.Sleep(250 * time.Millisecond)
        fmt.Printf("%d ", i)
    }
}
func alphabets() {
    for i := 'a'; i <= 'e'; i++ {
        time.Sleep(400 * time.Millisecond)
        fmt.Printf("%c ", i)
    }
}
func main() {
    go numbers()
    go alphabets()
    time.Sleep(3000 * time.Millisecond)
    fmt.Println("main terminated")
}
```

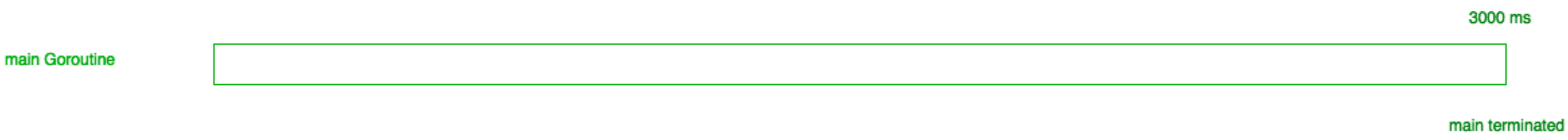
```
1 a 2 3 b 4 c 5 d e main terminated

Program exited.
```

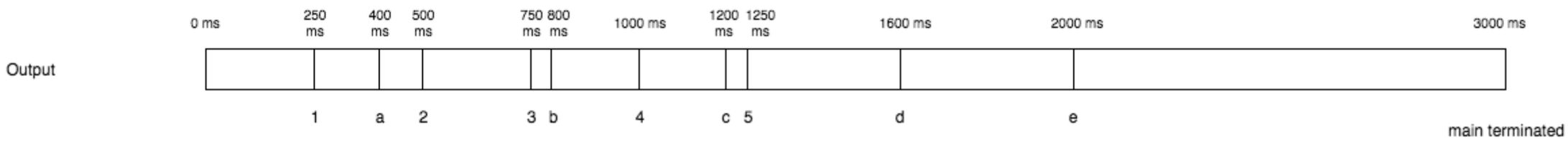
Goroutine Example




```
1 a 2 3 b 4 c 5 d e main terminated

Program exited.
```







Experiments

```go
package main

import (
    "fmt"
    "time"
)

func say(s string) {
    for i := 0; i < 10; i++ {
        fmt.Println(s, "***", i)
    }
}

func main() {
    // 함수를 동기적으로 실행
    say("Sync")

    // 함수를 비동기적으로 실행
    go say("Async1")
    go say("Async2")
    go say("Async3")

    // 3초 대기
    time.Sleep(time.Second * 3)
}
```

익명함수

```go
package main

func main() {
    sum := func(n ...int) int { //익명함수 정의
        s := 0
        for _, i := range n {
            s += i
        }
        return s
    }

    result := sum(1, 2, 3, 4, 5) //익명함수 호출
    println(result)
}
```

- 함수명을 갖지 않는 함수를 익명함수(Anonymous Function)

일급함수

- Go 프로그래밍 언어에서 함수는 일급함수로서 Go의 기본 타입과 동일하게 취급
  - 따라서 다른 함수의 파라미터로 전달하거나 다른 함수의 리턴값으로도 사용될 수 있음
  - 즉, 함수의 입력 파라미터나 리턴 파라미터로서 함수 자체가 사용될 수 있음

일급함수

```go
package main

func main() {
    //변수 add 에 익명함수 할당
    add := func(i int, j int) int {
        return i + j
    }

    // add 함수 전달
    r1 := calc(add, 10, 20)
    println(r1)

    // 직접 첫번째 파라미터에 익명함수를 정의함
    r2 := calc(func(x int, y int) int { return x - y }, 10, 20)
    println(r2)

}

func calc(f func(int, int) int, a int, b int) int {
    result := f(a, b)
    return result
}
```

```go
// 원형 정의
type calculator func(int, int) int

// calculator 원형 사용
func calc(f calculator, a int, b int) int {
    result := f(a, b)
    return result
}
```

Experiments

- Anonymous 익명함수 이용한 루틴

```go
package main

import (
    "fmt"
    "time"
)

func function() {
    for i := 0; i < 10; i++ {
        fmt.Print(i)
    }
    fmt.Println()
}

func main() {
    go function()

    go func() {
        for i := 10; i < 20; i++ {
            fmt.Print(i, " ")
        }
    }()

    time.Sleep(1 * time.Second)
}

```

Wait with sync.WaitGroup

```go
package main

import (
    "flag"
    "fmt"
    "sync"
)

func main() {
    n := flag.Int( name: "n",  value: 20,  usage: "Number of goroutines")
    flag.Parse()
    count := *n
    fmt.Printf( format: "Going to create %d goroutines.\n", count)

    var waitGroup sync.WaitGroup

    fmt.Printf( format: "%#v\n", waitGroup)
    for i := 0; i < count; i++ {
        waitGroup.Add( delta: 1)
        go func(x int) {
            defer waitGroup.Done()
            fmt.Printf( format: "%d ", x)
        }(i)
    }

    fmt.Printf( format: "%#v\n", waitGroup)

    waitGroup.Wait()

    fmt.Println( a...: "\nExiting...")
}
```

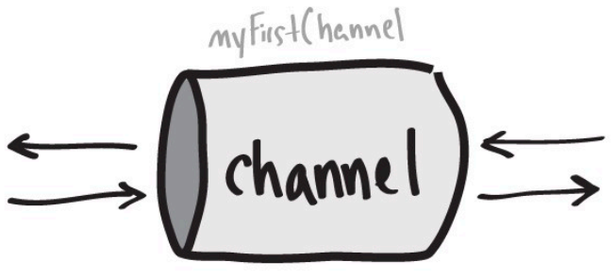
```go
var waitGroup sync.WaitGroup
```

- When launching a goroutine, waitGroup.Add(1)
- Program ends with waitGroupWait()

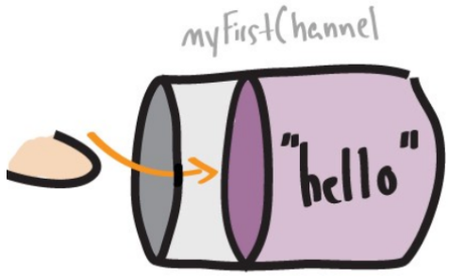
Channel

- Channels allow go routines to communicate with each other.

- A channel is like a pipe, from which go routines can send and receive information from other go routines.




```
myFirstChannel := make(chan string)
```




```
myFirstChannel <- "hello" // Send
myVariable := <- myFirstChannel // Receive
```

Channel

```go
package main

import (
    "fmt"
    "math/rand"
)

func random(min, max int) int {
    return rand.Intn(max-min) + min
}

func main() {
    // create new channel of type int
    ch := make(chan int)

    // start new anonymous goroutine
    go func() {
        snd := random( min: 10, max: 20)
        fmt.Println( a...: "sending", snd)
        // send 42 to channel
        ch <- snd
    }()
    // read from channel
    rcv := <-ch
    fmt.Println( a...: "receiving",rcv)
}
```

https://divan.dev/posts/go_concurrency_visualize/

Great Work!

- GopherCon 2016: Ivan Danyliuk - Visualizing Concurrency in Go

- https://www.youtube.com/watch?v=KyuFeiG3Y60

- https://divan.dev/posts/go_concurrency_visualize/

Channel

```go
package main

import "time"

func timer(d time.Duration) <-chan int {
    c := make(chan int)
    go func() {
        time.Sleep(d)
        c <- 1
    }()
    return c
}

func main() {
    for i := 0; i < 24; i++ {
        c := timer(1 * time.Second)
        <-c
    }
}
```

Channel
Ping-Pong 2 Players

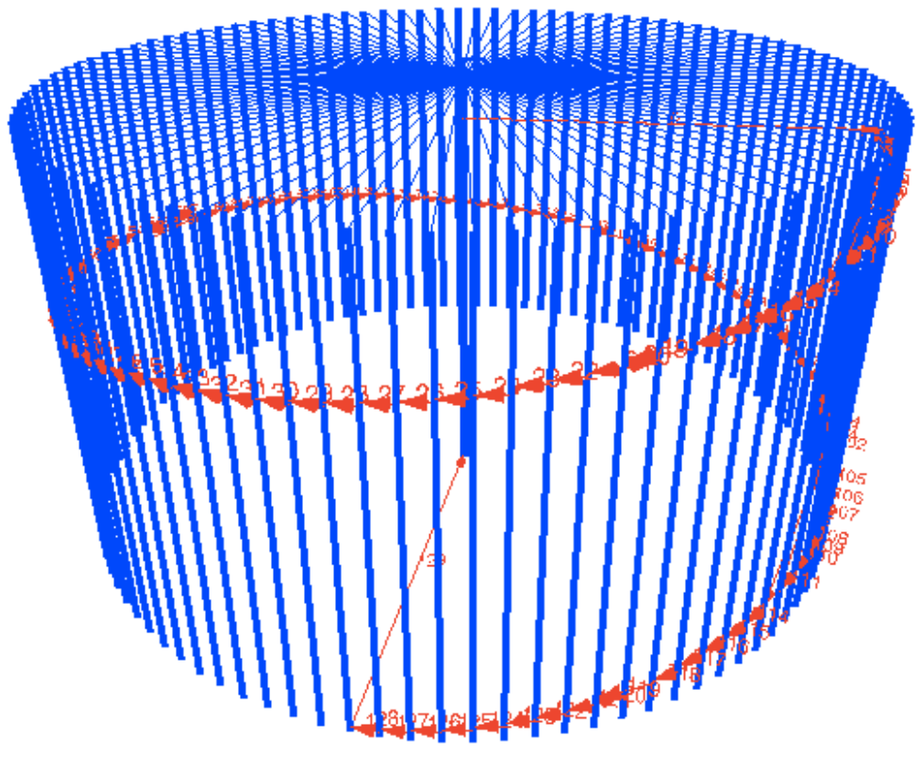
```go
package main

import "time"

func main() {
    var Ball int
    table := make(chan int)
    go player(table)
    go player(table)

    table <- Ball
    time.Sleep(1 * time.Second)
    <-table
}

func player(table chan int) {
    for {
        ball := <-table
        ball++
        time.Sleep(100 * time.Millisecond)
        table <- ball
    }
}
```

Channel
Ping-Pong 3 Players

```go
package main

import "time"

func main() {
    var Ball int
    table := make(chan int)
    go player(table)
    go player(table)

    table <- Ball
    time.Sleep(1 * time.Second)
    <-table
}

func player(table chan int) {
    for {
        ball := <-table
        ball++
        time.Sleep(100 * time.Millisecond)
        table <- ball
    }
}
```

Channel
Ping-Pong 100 Players

```go
package main

import "time"

func main() {
    var Ball int
    table := make(chan int)
    go player(table)
    go player(table)

    table <- Ball
    time.Sleep(1 * time.Second)
    <-table
}

func player(table chan int) {
    for {
        ball := <-table
        ball++
        time.Sleep(100 * time.Millisecond)
        table <- ball
    }
}
```

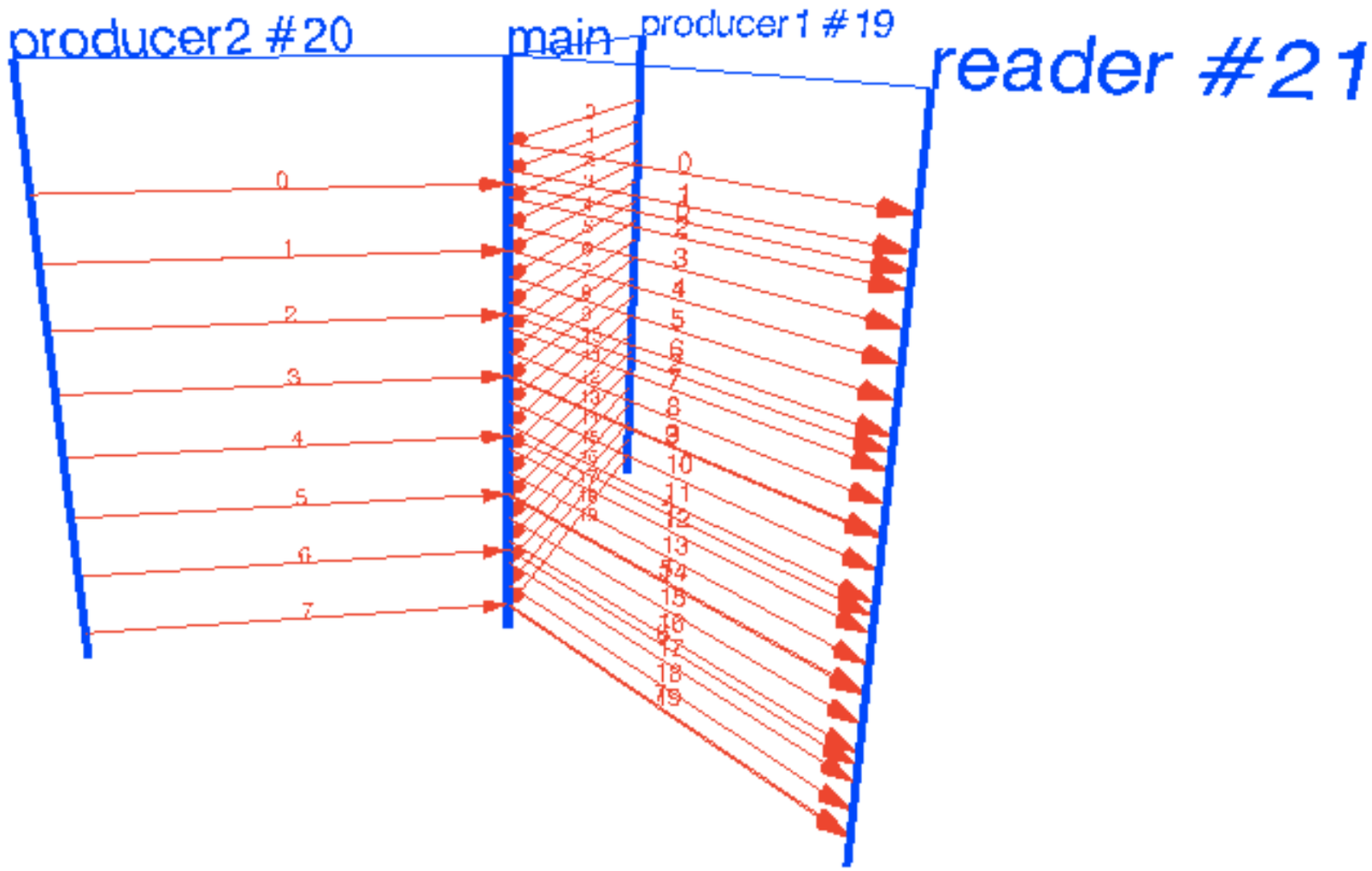


Channel: Producer-Consumer

```go
package main

import (
    "fmt"
    "time"
)

func producer(ch chan int, d time.Duration) {
    var i int
    for {
        ch <- i
        i++
        time.Sleep(d)
    }
}

func reader(out chan int) {
    for x := range out {
        fmt.Println(x)
    }
}
```

```go
func main() {
    ch := make(chan int)
    out := make(chan int)
    go producer(ch, 100*time.Millisecond)
    go producer(ch, 250*time.Millisecond)
    go reader(out)
    for i := range ch {
        out <- i
    }
}
```

Channel: Producer-Consumer



https://divan.dev/posts/go_concurrency_visualize/

In next class

- More about channel

- Go Scheduler