UNIX and security basics

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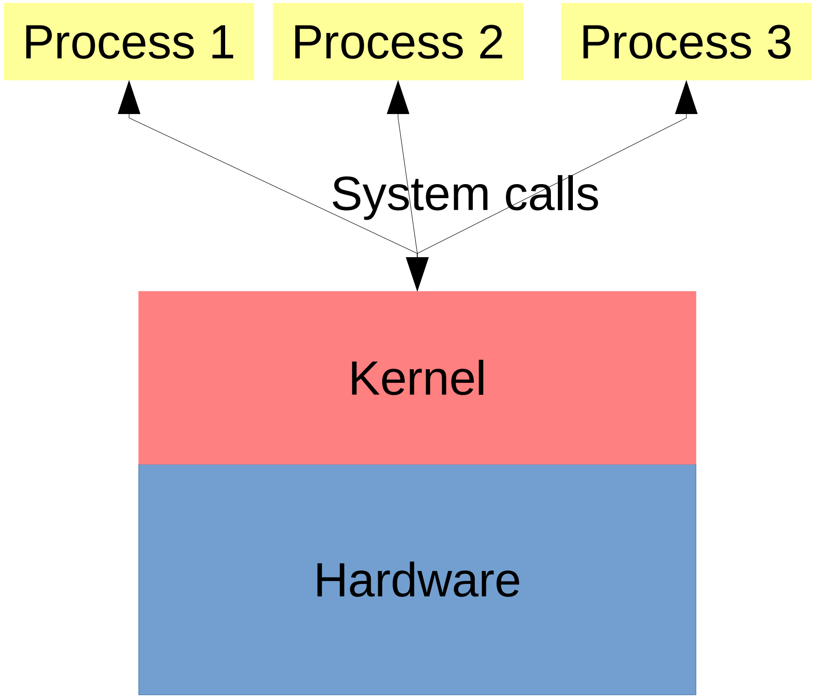
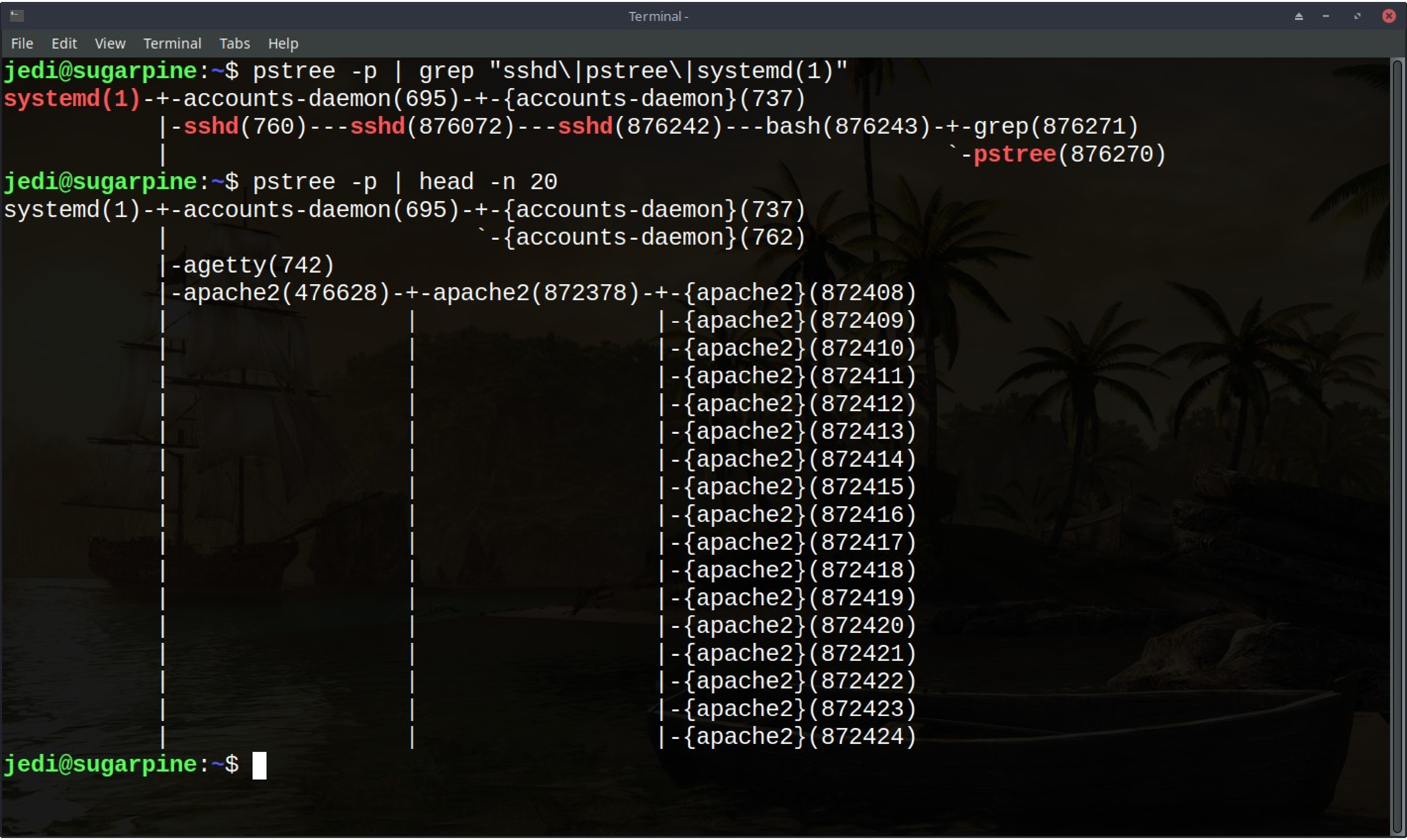
CSE 536 Spring 2026

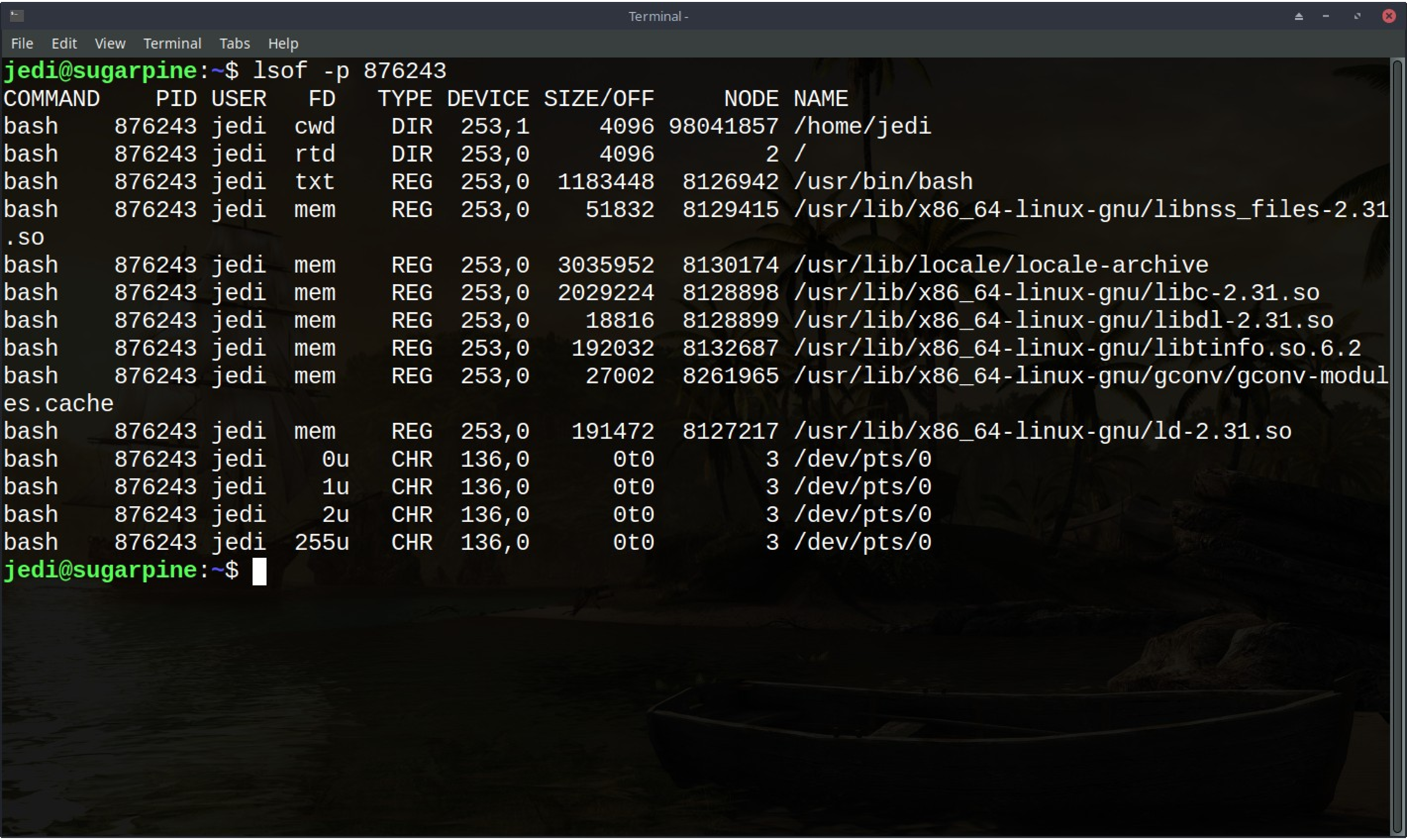
UNIX process hierarchy

```
pstree -p | less -S
pstree -pu jedi
lsof -p 31009
```

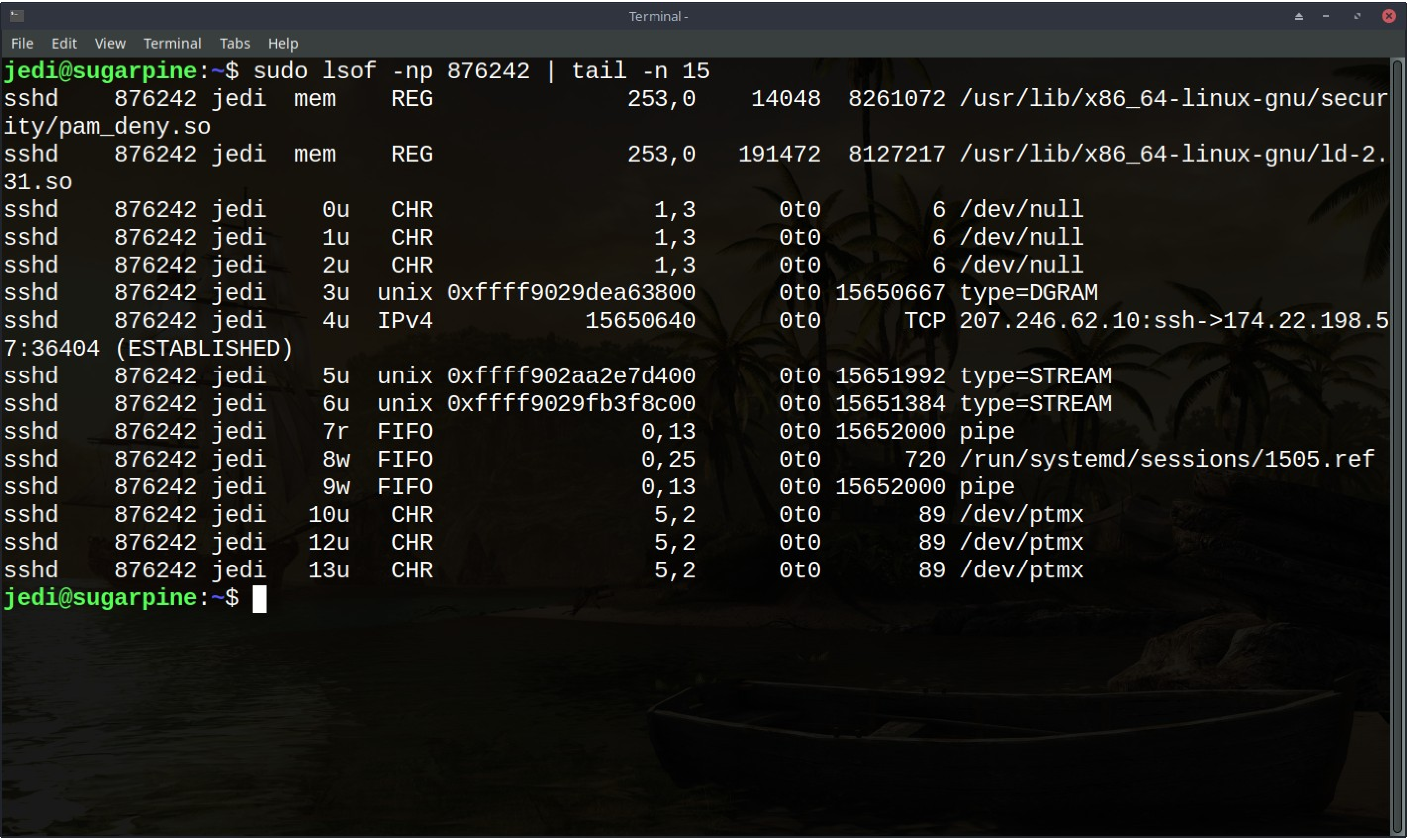




```
jedi@sugarpine:~$ pstree -p | grep "sshd\|pstree\|systemd(1)"
systemd(1)-+-accounts-daemon(695)-+-{accounts-daemon}(737)
           |-sshd(760)---sshd(876072)---sshd(876242)---bash(876243)-+-grep(876271)
           |                                                        `-pstree(876270)
jedi@sugarpine:~$ pstree -p | head -n 20
systemd(1)-+-accounts-daemon(695)-+-{accounts-daemon}(737)
           |                      `-{accounts-daemon}(762)
           |-agetty(742)
           |-apache2(476628)-+-apache2(872378)-+-{apache2}(872408)
           |                 |                 |-{apache2}(872409)
           |                 |                 |-{apache2}(872410)
           |                 |                 |-{apache2}(872411)
           |                 |                 |-{apache2}(872412)
           |                 |                 |-{apache2}(872413)
           |                 |                 |-{apache2}(872414)
           |                 |                 |-{apache2}(872415)
           |                 |                 |-{apache2}(872416)
           |                 |                 |-{apache2}(872417)
           |                 |                 |-{apache2}(872418)
           |                 |                 |-{apache2}(872419)
           |                 |                 |-{apache2}(872420)
           |                 |                 |-{apache2}(872421)
           |                 |                 |-{apache2}(872422)
           |                 |                 |-{apache2}(872423)
           |                 |                 |-{apache2}(872424)
jedi@sugarpine:~$ 
```

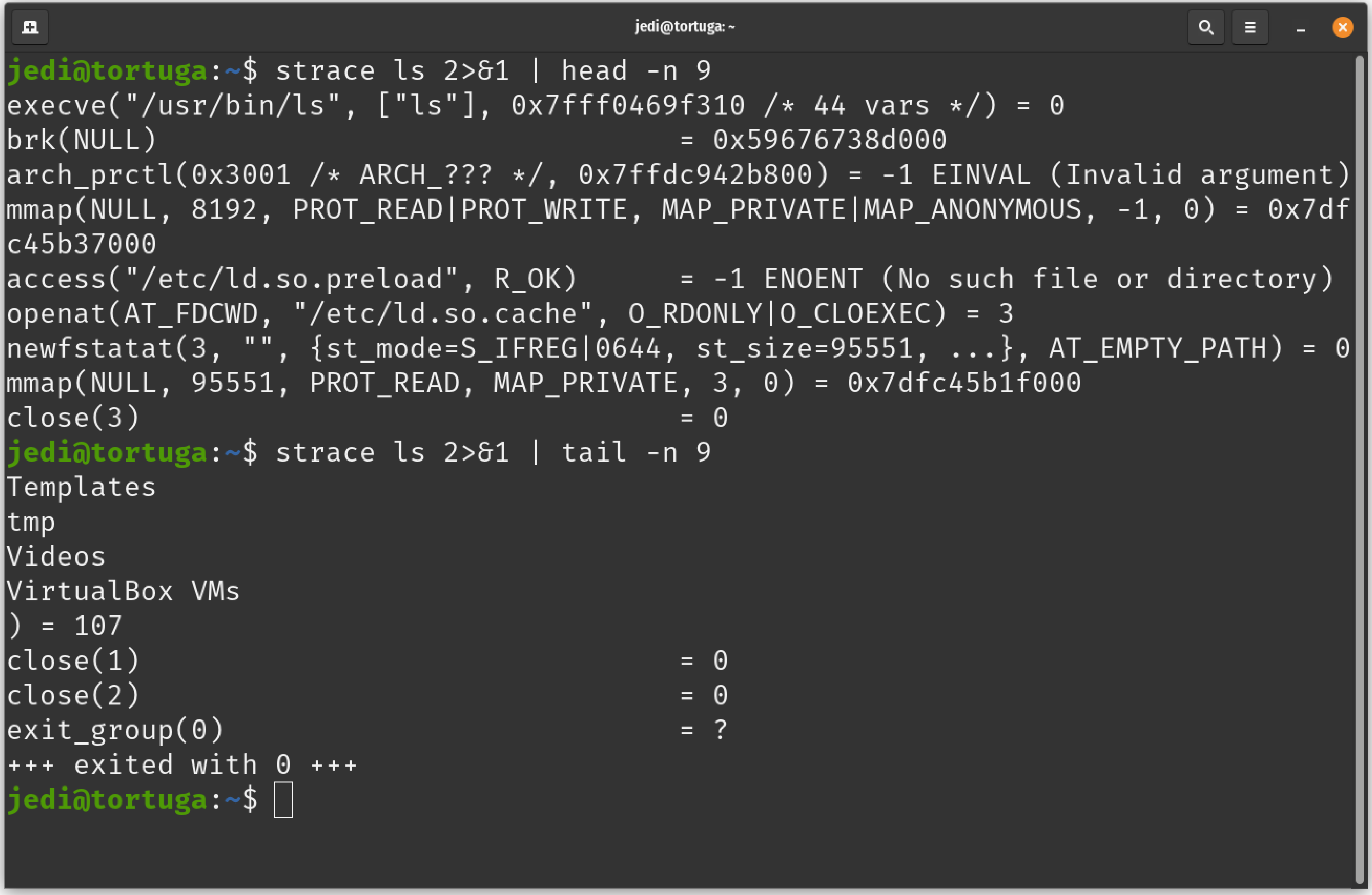


```
jedi@sugarpine:~$ lsof -p 876243
COMMAND     PID USER   FD   TYPE DEVICE SIZE/OFF     NODE NAME
bash    876243 jedi  cwd    DIR  253,1     4096 98041857 /home/jedi
bash    876243 jedi  rtd    DIR  253,0     4096        2 /
bash    876243 jedi  txt    REG  253,0  1183448  8126942 /usr/bin/bash
bash    876243 jedi  mem    REG  253,0    51832  8129415 /usr/lib/x86_64-linux-gnu/libnss_files-2.31
.so
bash    876243 jedi  mem    REG  253,0  3035952  8130174 /usr/lib/locale/locale-archive
bash    876243 jedi  mem    REG  253,0  2029224  8128898 /usr/lib/x86_64-linux-gnu/libc-2.31.so
bash    876243 jedi  mem    REG  253,0    18816  8128899 /usr/lib/x86_64-linux-gnu/libdl-2.31.so
bash    876243 jedi  mem    REG  253,0   192032  8132687 /usr/lib/x86_64-linux-gnu/libtinfo.so.6.2
bash    876243 jedi  mem    REG  253,0    27002  8261965 /usr/lib/x86_64-linux-gnu/gconv/gconv-modul
es.cache
bash    876243 jedi  mem    REG  253,0   191472  8127217 /usr/lib/x86_64-linux-gnu/ld-2.31.so
bash    876243 jedi    0u   CHR  136,0      0t0        3 /dev/pts/0
bash    876243 jedi    1u   CHR  136,0      0t0        3 /dev/pts/0
bash    876243 jedi    2u   CHR  136,0      0t0        3 /dev/pts/0
bash    876243 jedi  255u   CHR  136,0      0t0        3 /dev/pts/0
jedi@sugarpine:~$
```



```
jedi@sugarpine:~$ sudo lsof -np 876242 | tail -n 15
sshd    876242 jedi  mem    REG              253,0    14048  8261072 /usr/lib/x86_64-linux-gnu/secur
ity/pam_deny.so
sshd    876242 jedi  mem    REG              253,0   191472  8127217 /usr/lib/x86_64-linux-gnu/ld-2.
31.so
sshd    876242 jedi    0u   CHR                1,3      0t0        6 /dev/null
sshd    876242 jedi    1u   CHR                1,3      0t0        6 /dev/null
sshd    876242 jedi    2u   CHR                1,3      0t0        6 /dev/null
sshd    876242 jedi    3u  unix 0xffff9029dea63800      0t0 15650667 type=DGRAM
sshd    876242 jedi    4u  IPv4           15650640      0t0      TCP 207.246.62.10:ssh->174.22.198.5
7:36404 (ESTABLISHED)
sshd    876242 jedi    5u  unix 0xffff902aa2e7d400      0t0 15651992 type=STREAM
sshd    876242 jedi    6u  unix 0xffff9029fb3f8c00      0t0 15651384 type=STREAM
sshd    876242 jedi    7r  FIFO               0,13      0t0 15652000 pipe
sshd    876242 jedi    8w  FIFO               0,25      0t0      720 /run/systemd/sessions/1505.ref
sshd    876242 jedi    9w  FIFO               0,13      0t0 15652000 pipe
sshd    876242 jedi   10u   CHR                5,2      0t0       89 /dev/ptmx
sshd    876242 jedi   12u   CHR                5,2      0t0       89 /dev/ptmx
sshd    876242 jedi   13u   CHR                5,2      0t0       89 /dev/ptmx
jedi@sugarpine:~$ 
```

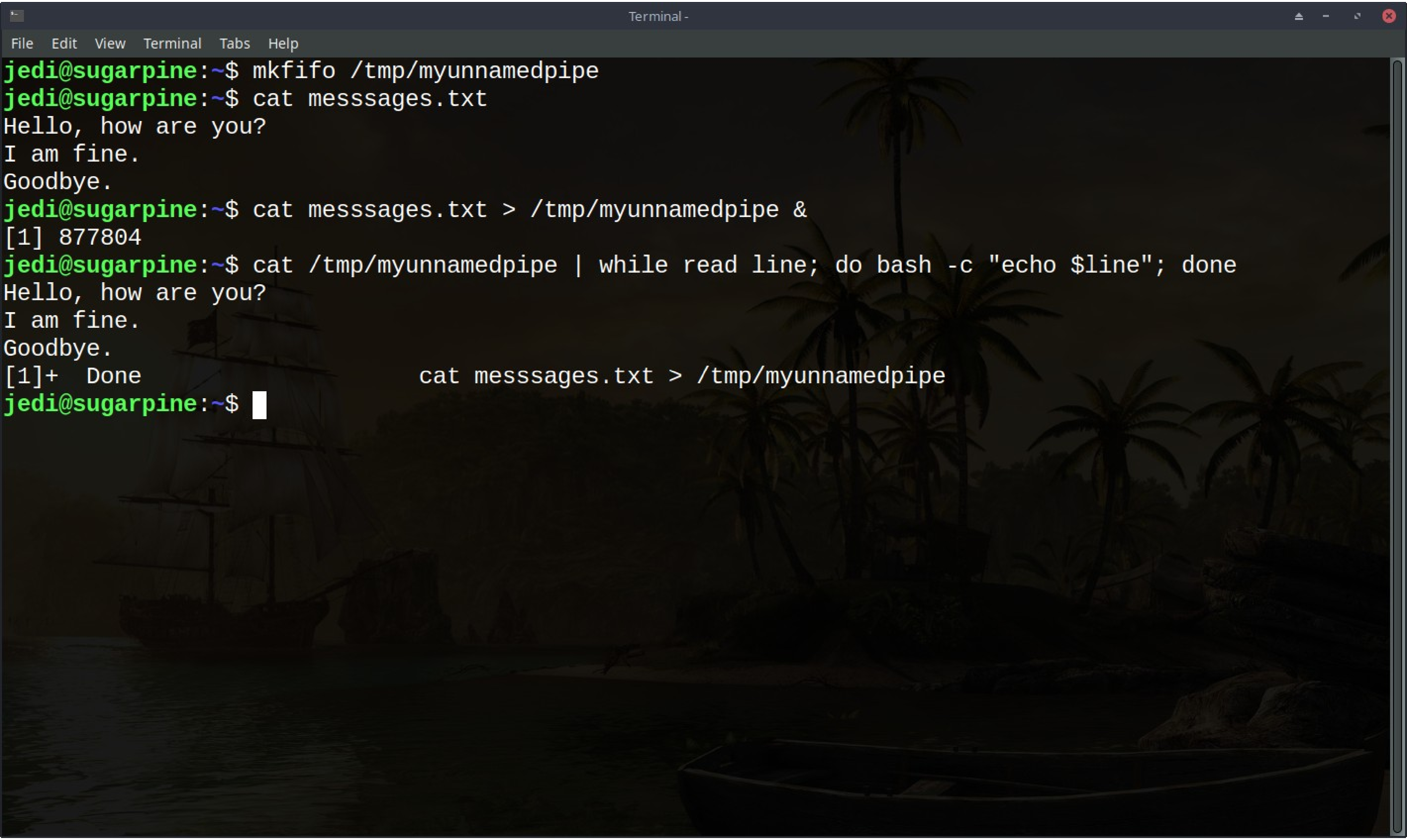
System Calls



```
jedi@tortuga:~$ strace ls 2>&1 | head -n 9
execve("/usr/bin/ls", ["ls"], 0x7fff0469f310 /* 44 vars */) = 0
brk(NULL)                               = 0x59676738d000
arch_prctl(0x3001 /* ARCH_??? */, 0x7ffdc942b800) = -1 EINVAL (Invalid argument)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7df
c45b37000
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=95551, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 95551, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7dfc45b1f000
close(3)                                = 0
jedi@tortuga:~$ strace ls 2>&1 | tail -n 9
Templates
tmp
Videos
VirtualBox VMs
) = 107
close(1)                                = 0
close(2)                                = 0
exit_group(0)                           = ?
+++ exited with 0 +++
jedi@tortuga:~$ 
```

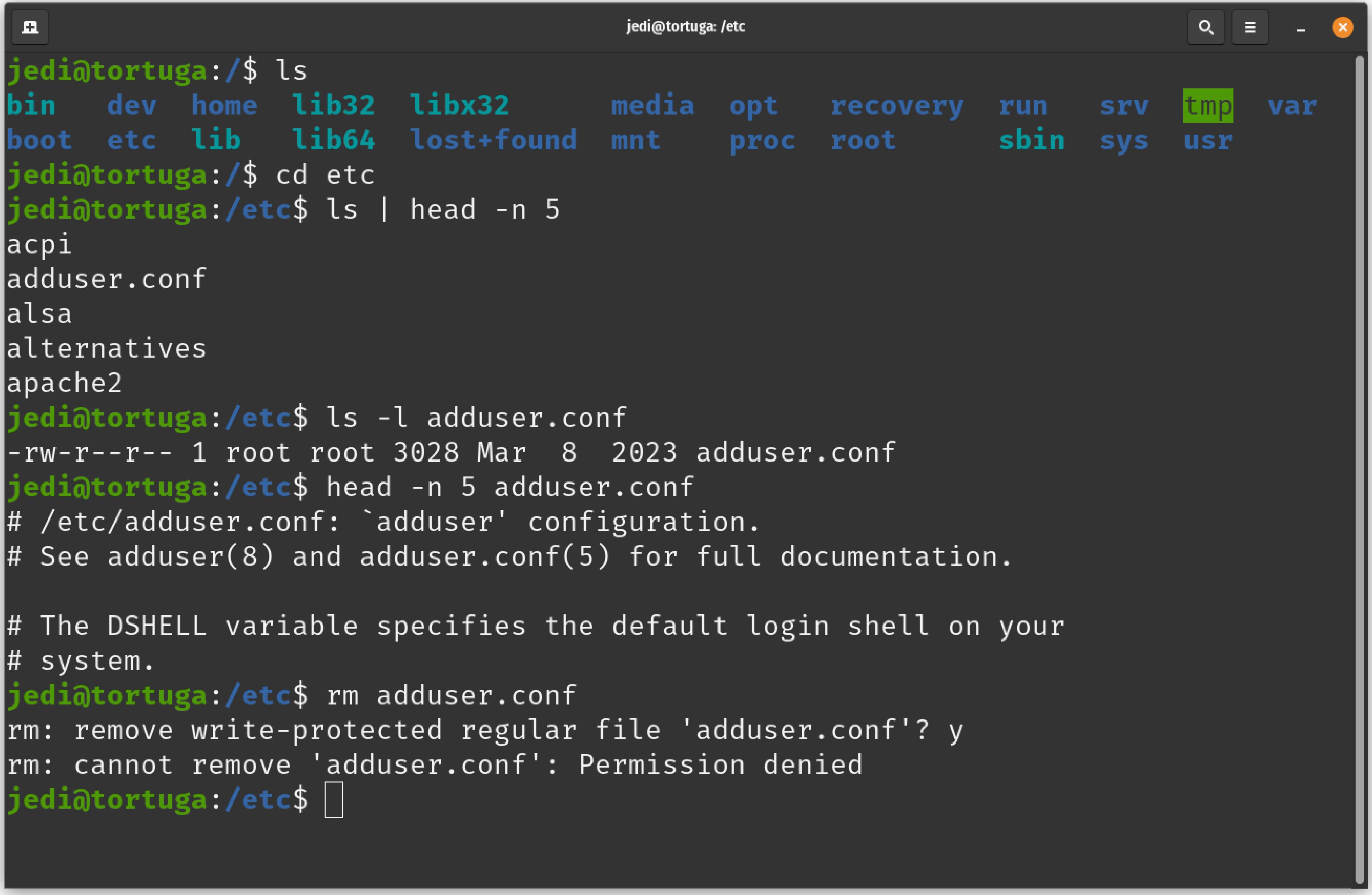
Interprocess Communication (IPC)

- Sockets
  - Datagram or stream
- Pipes
  - Named or unnamed
- Other ways for processes to communicate
  - Command line arguments, shared memory, file I/O, *etc.*



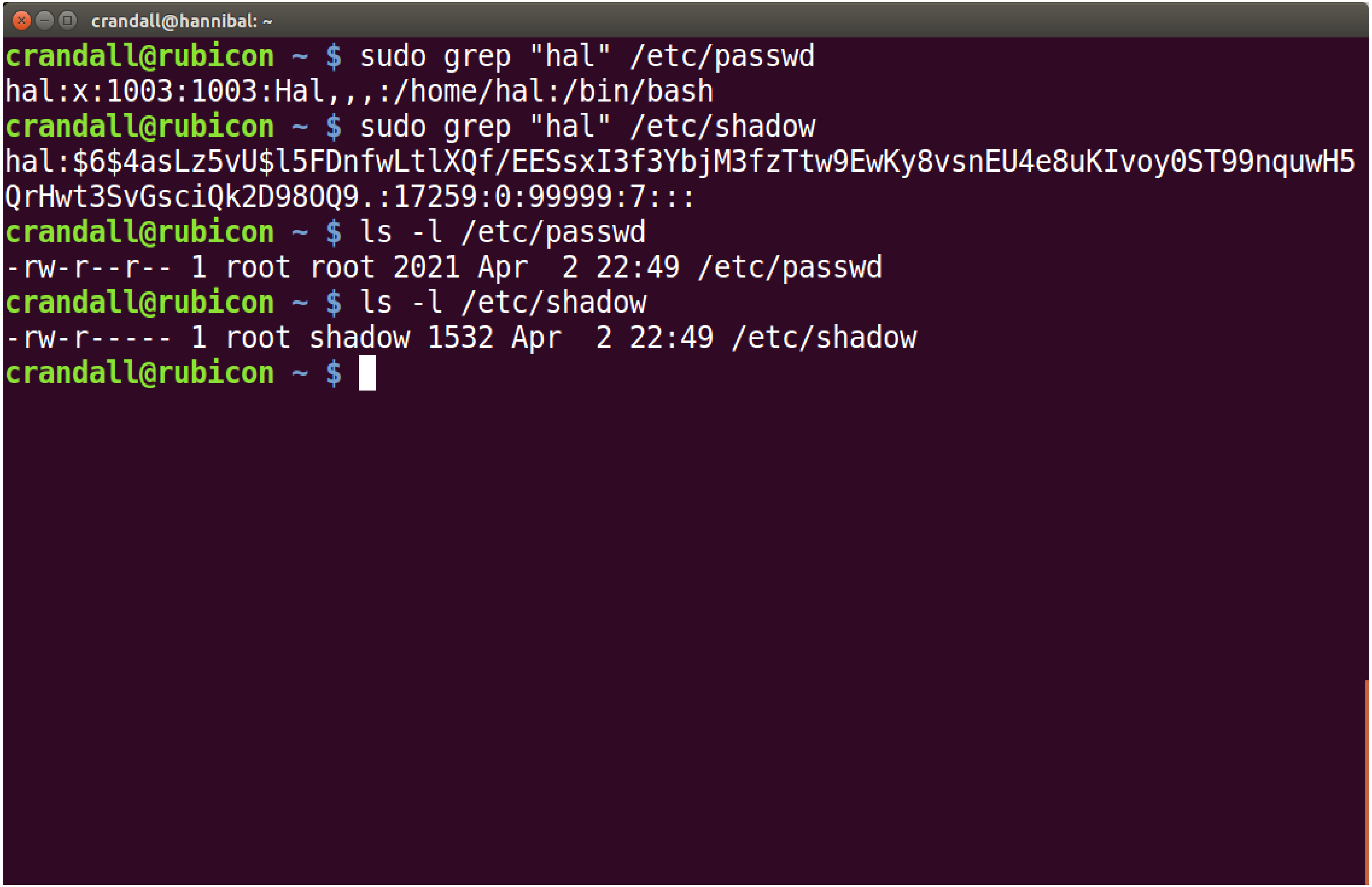
```
jedi@sugarpine:~$ mkfifo /tmp/myunnamedpipe
jedi@sugarpine:~$ cat messsages.txt
Hello, how are you?
I am fine.
Goodbye.
jedi@sugarpine:~$ cat messsages.txt > /tmp/myunnamedpipe &
[1] 877804
jedi@sugarpine:~$ cat /tmp/myunnamedpipe | while read line; do bash -c "echo $line"; done
Hello, how are you?
I am fine.
Goodbye.
[1]+  Done                    cat messsages.txt > /tmp/myunnamedpipe
jedi@sugarpine:~$ 
```

Filesystem



```
jedi@tortuga:/$ ls
bin   dev  home  lib32  libx32      media  opt   recovery  run   srv  tmp  var
boot  etc  lib   lib64  lost+found  mnt    proc  root      sbin  sys  usr
jedi@tortuga:/$ cd etc
jedi@tortuga:/etc$ ls | head -n 5
acpi
adduser.conf
alsa
alternatives
apache2
jedi@tortuga:/etc$ ls -l adduser.conf
-rw-r--r-- 1 root root 3028 Mar  8  2023 adduser.conf
jedi@tortuga:/etc$ head -n 5 adduser.conf
# /etc/adduser.conf: `adduser' configuration.
# See adduser(8) and adduser.conf(5) for full documentation.

# The DSHELL variable specifies the default login shell on your
# system.
jedi@tortuga:/etc$ rm adduser.conf
rm: remove write-protected regular file 'adduser.conf'? y
rm: cannot remove 'adduser.conf': Permission denied
jedi@tortuga:/etc$ 
```

File permissions



```
crandall@rubicon ~ $ sudo grep "hal" /etc/passwd
hal:x:1003:1003:Hal,,,:/home/hal:/bin/bash
crandall@rubicon ~ $ sudo grep "hal" /etc/shadow
hal:$6$4asLz5vU$l5FDnfwLtlXQf/EESsxI3f3YbjM3fzTtw9EwKy8vsnEU4e8uKIvoy0ST99nquwH5
QrHwt3SvGsciQk2D98OQ9.:17259:0:99999:7:::
crandall@rubicon ~ $ ls -l /etc/passwd
-rw-r--r-- 1 root root 2021 Apr  2 22:49 /etc/passwd
crandall@rubicon ~ $ ls -l /etc/shadow
-rw-r----- 1 root shadow 1532 Apr  2 22:49 /etc/shadow
crandall@rubicon ~ $ 
```

-rwxr-x---

- First is special designations (symlink, directory)
- Next triplet is user (u)
- Triplet after is group (g)
- Last triplet is others (o)
- r = read, w = write, x = execute
- Sometimes you'll see other things, like s for Set UID

Authentication in general

- Bishop, *Computer Security: Art and Science*... “Authentication is the binding of an identity to a principal. Network-based authentication mechanisms require a principal to authenticate to a single system, either local or remote. The authentication is then propagated.”

Authentication in general (continued)

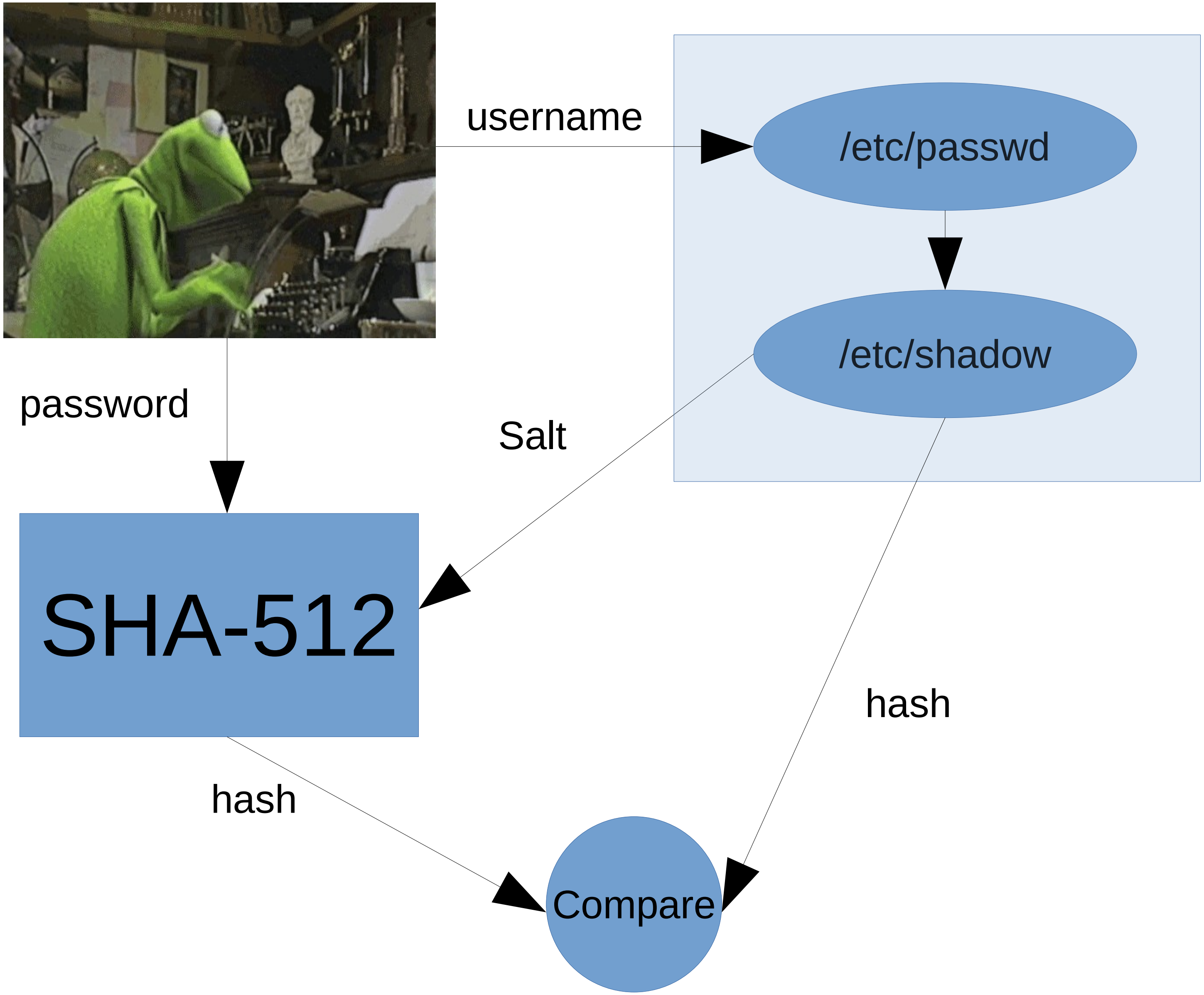
- Bishop: “Authentication consists of an entity, the *user*, trying to convince a different entity, the *verifier*, of the user's identity. The user does so by claiming to know some information, to possess something, to have some particular set of physical characteristics, or to be in a specific location.”
- Informally: something you know, something you have, something you are

2FA = 2-Factor Authentication

- Two of these:
  - Something you know
  - Something you have
  - Something you are
- *E.g.*, bank card plus PIN
- For Internet services, typically the first two
- Helps protect against phishing, for example

Basic Linux authentication

- Ties you (the identity) to your user ID (the principal), which is in turn tied to subjects (*e.g.*, processes) and objects (*e.g.*, files)
- Based on hashing
  - Also salting
  - Also shadowed password hashes



username

/etc/passwd

/etc/shadow

password

Salt

SHA-512

hash

hash

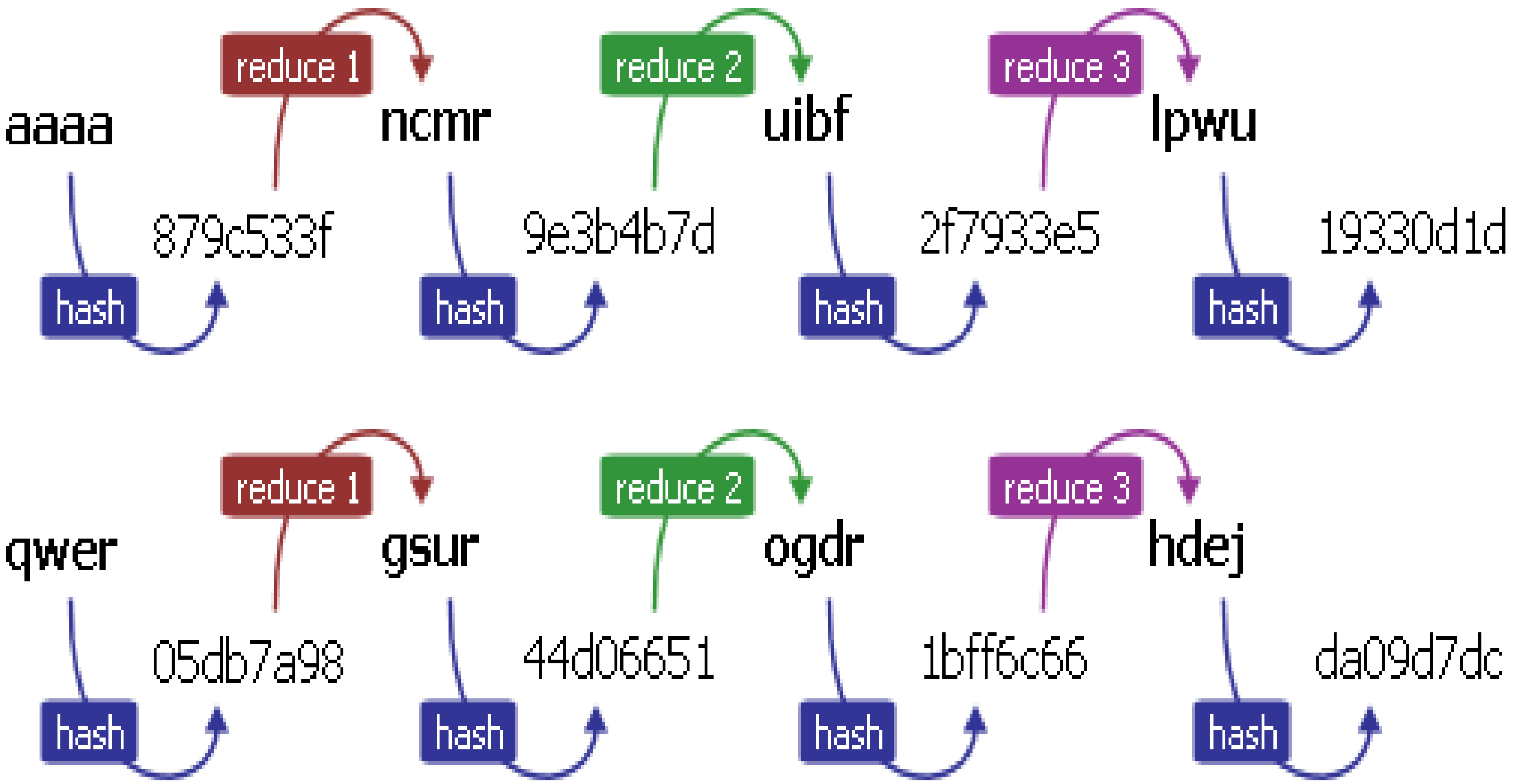
Compare

Match? Yes or no.

Passwords

- Should be high ~~entropy,~~ algorithmic complexity
- Should be easy to remember

These requirements are in conflict with each other! Password managers help.



Rainbow Table

aaaa	19330d1d
qwer	da09d7dc

Plagiarized from https://i.imgsafe.org/2bf87cbfe2.png

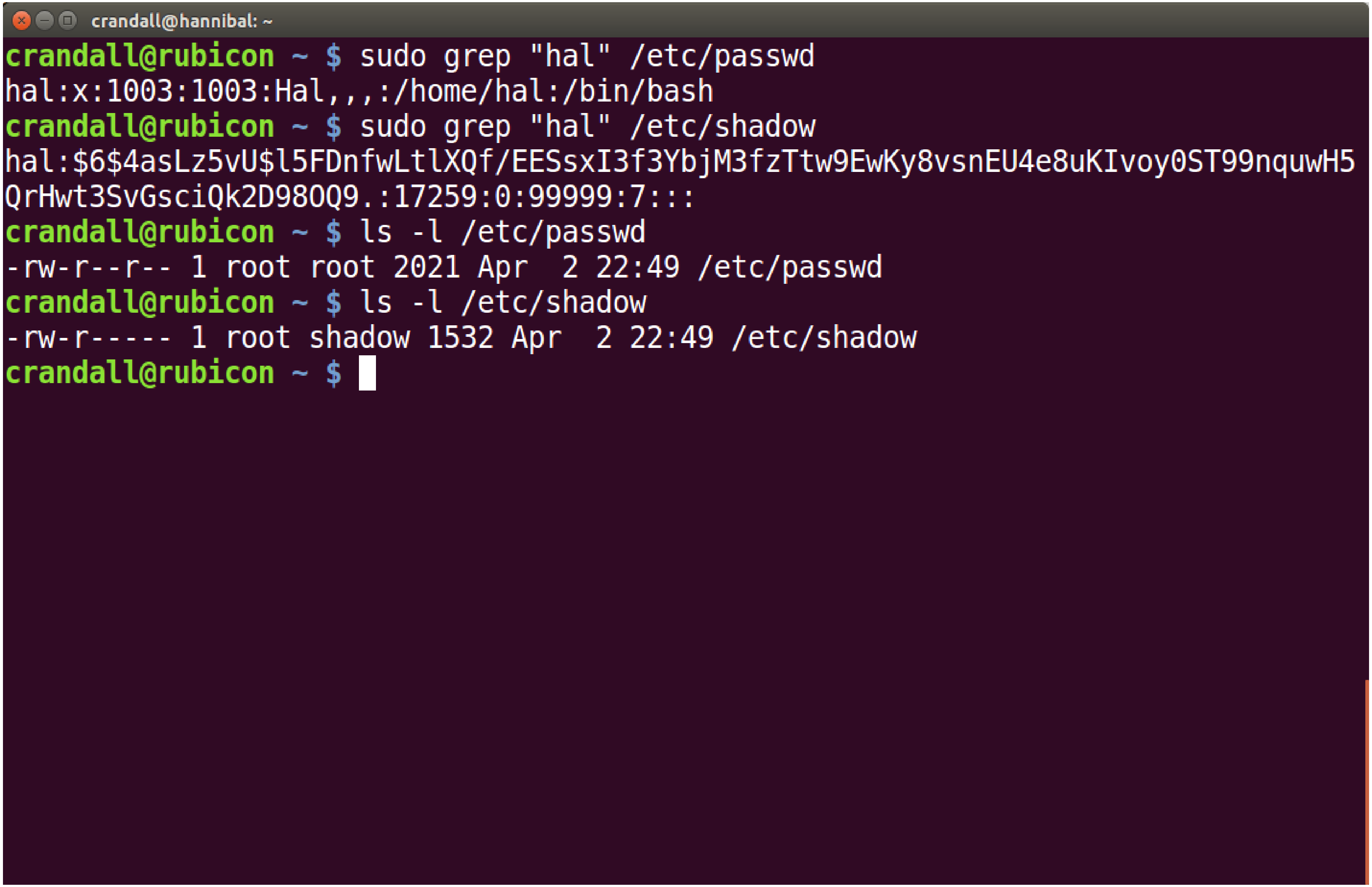
Time-memory tradeoff

- Rainbow tables can store lots of hash results compactly (precomputation)
- Just check if a user's hash might be in a hash chain, only recalculate it if so
- As a fall-back, just try every possible password (brute force)

Salting helps against precomputation.

Good passwords, system-imposed delays, shadowing help against brute force.

Shadowing the password file



```
crandall@rubicon ~ $ sudo grep "hal" /etc/passwd
hal:x:1003:1003:Hal,,,:/home/hal:/bin/bash
crandall@rubicon ~ $ sudo grep "hal" /etc/shadow
hal:$6$4asLz5vU$l5FDnfwLtlXQf/EESsxI3f3YbjM3fzTtw9EwKy8vsnEU4e8uKIvoy0ST99nquwH5
QrHwt3SvGsciQk2D98OQ9.:17259:0:99999:7:::
crandall@rubicon ~ $ ls -l /etc/passwd
-rw-r--r-- 1 root root 2021 Apr  2 22:49 /etc/passwd
crandall@rubicon ~ $ ls -l /etc/shadow
-rw-r----- 1 root shadow 1532 Apr  2 22:49 /etc/shadow
crandall@rubicon ~ $ 
```

What is a vulnerability?

- Management information stored in-band with regular information?
- Programming the weird machine?
- A failure to properly sanitize inputs?
- Mostly have one of two flavors:
  - One process (can be through local or IPC) sends inputs to another process that trick it into accessing or changing something it shouldn’t.
  - A process makes system calls to the kernel and tricks it in some way.

Can be local or remote, sometimes something else

- Send malicious input over a network socket to take control of a remote machine
- Give malicious input to a privileged local process to get escalated privileges for yourself
- Confuse the logic of an accounting mechanism
- Break the separation between web sites in a browser to get access to someone's bank credentials

Plagiarized from
https://sites.psu.edu/thedeepweb/2015/09/17/captain-crunch-and-his-toy-whistle/

Other examples of logic bugs or more general vulnerabilities?

- Werewolves has a couple
- Amazon shopping cart (there was an IEEE Symposium on Security and Privacy paper about this, but I can't find it)
- Pouring salt water or putting tabs from construction sites in Coke machines
- Getting a code out of a locked locker
- Other examples you know of?

SQL command injection

SELECT * where username = '$u' and password = '$p'

$u = crandall
$p = abc123

SELECT * where username = 'crandall' and password = 'abc123'

SQL command injection

SELECT * where username = '$u' and password = '$p'

$u = bla' or '1' = '1' --
$p = idontknow

SELECT * where username = 'bla' or '1' = '1' --' and password = 'idontknow'

SQL command injection

```
SELECT * where username = '$u' and password = '$p'

$u = bla' or '1' = '1' --
$p = idontknow

SELECT * where username = 'bla' or '1' = '1' --' and password = 'idontknow'
```

Wassermann and Su, POPL 2006

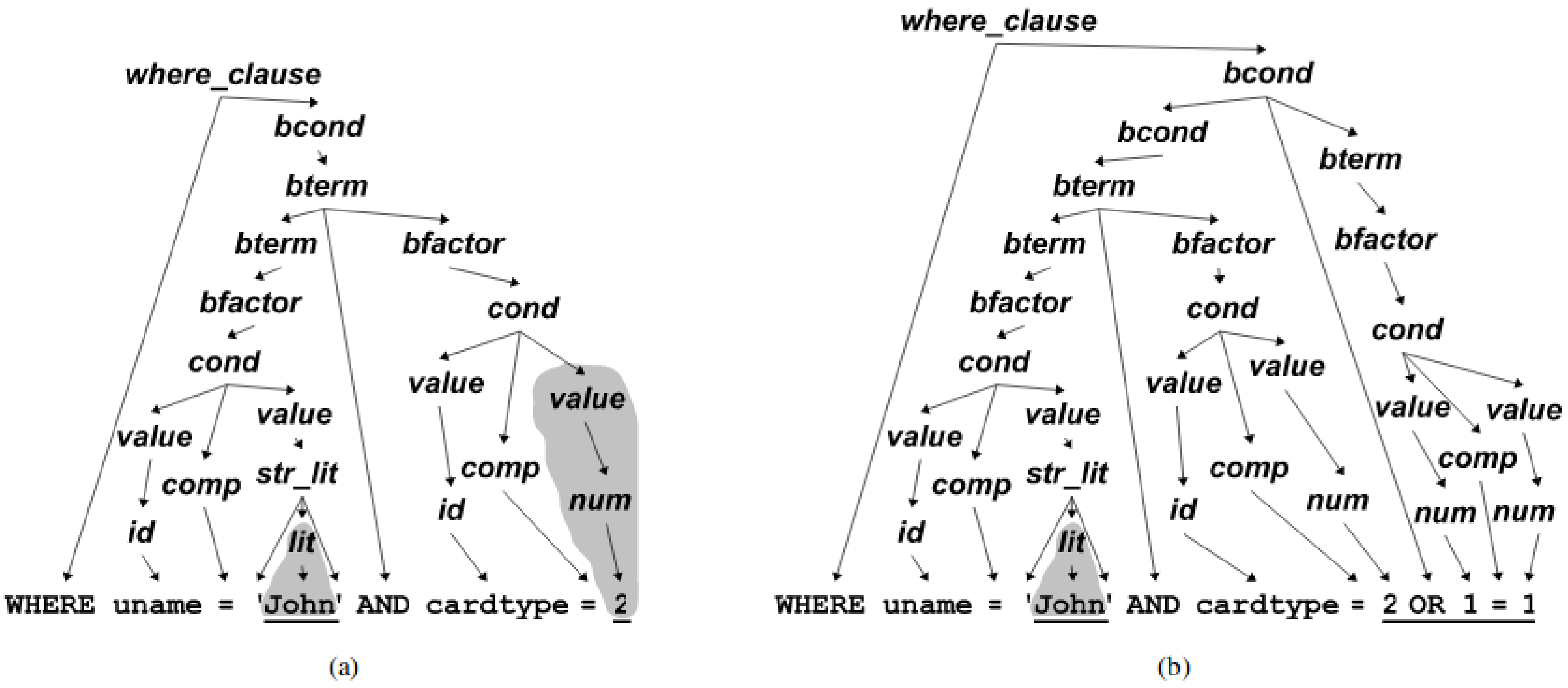
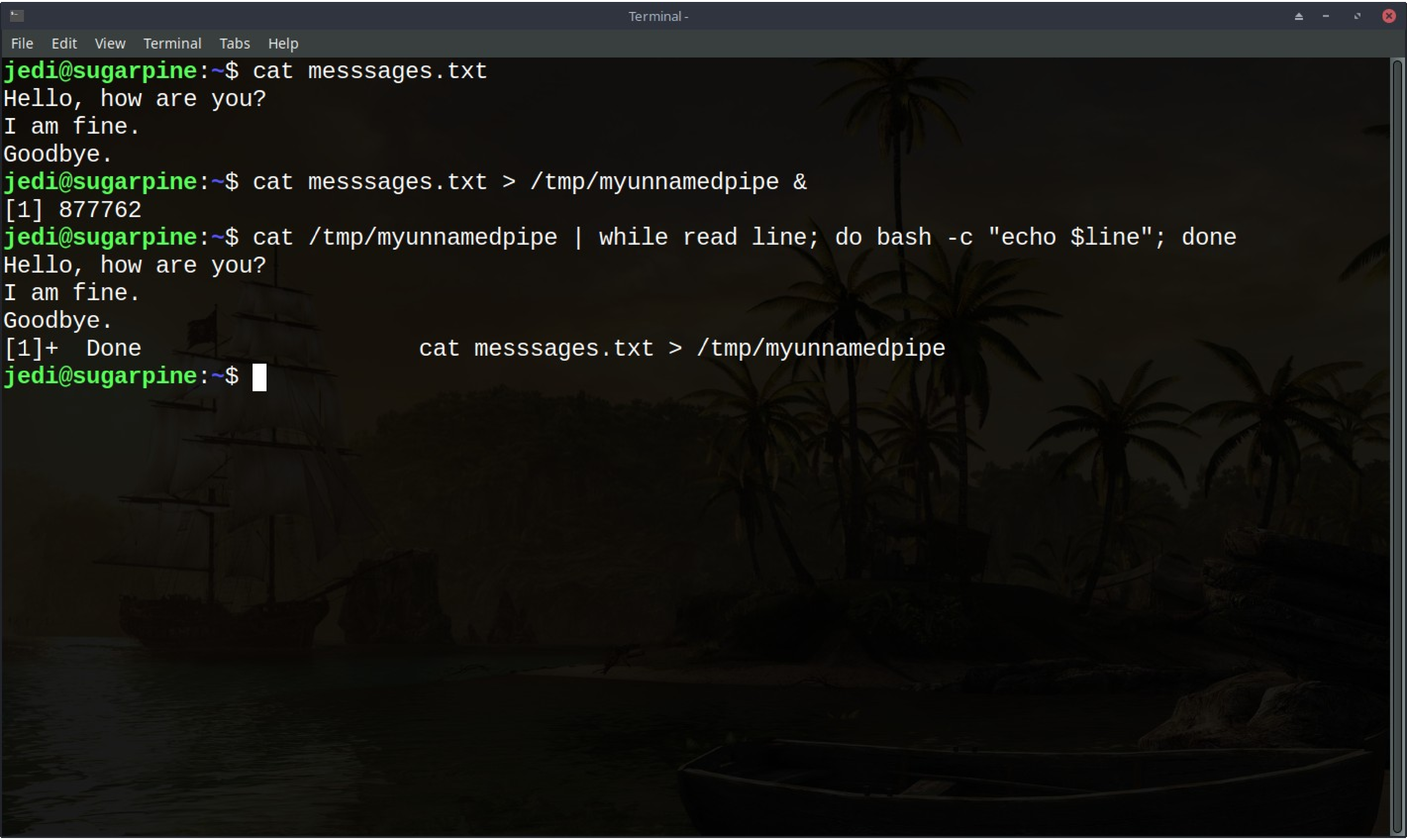


Figure 4. Parse trees for WHERE clauses of generated queries. Substrings from user input are underlined.

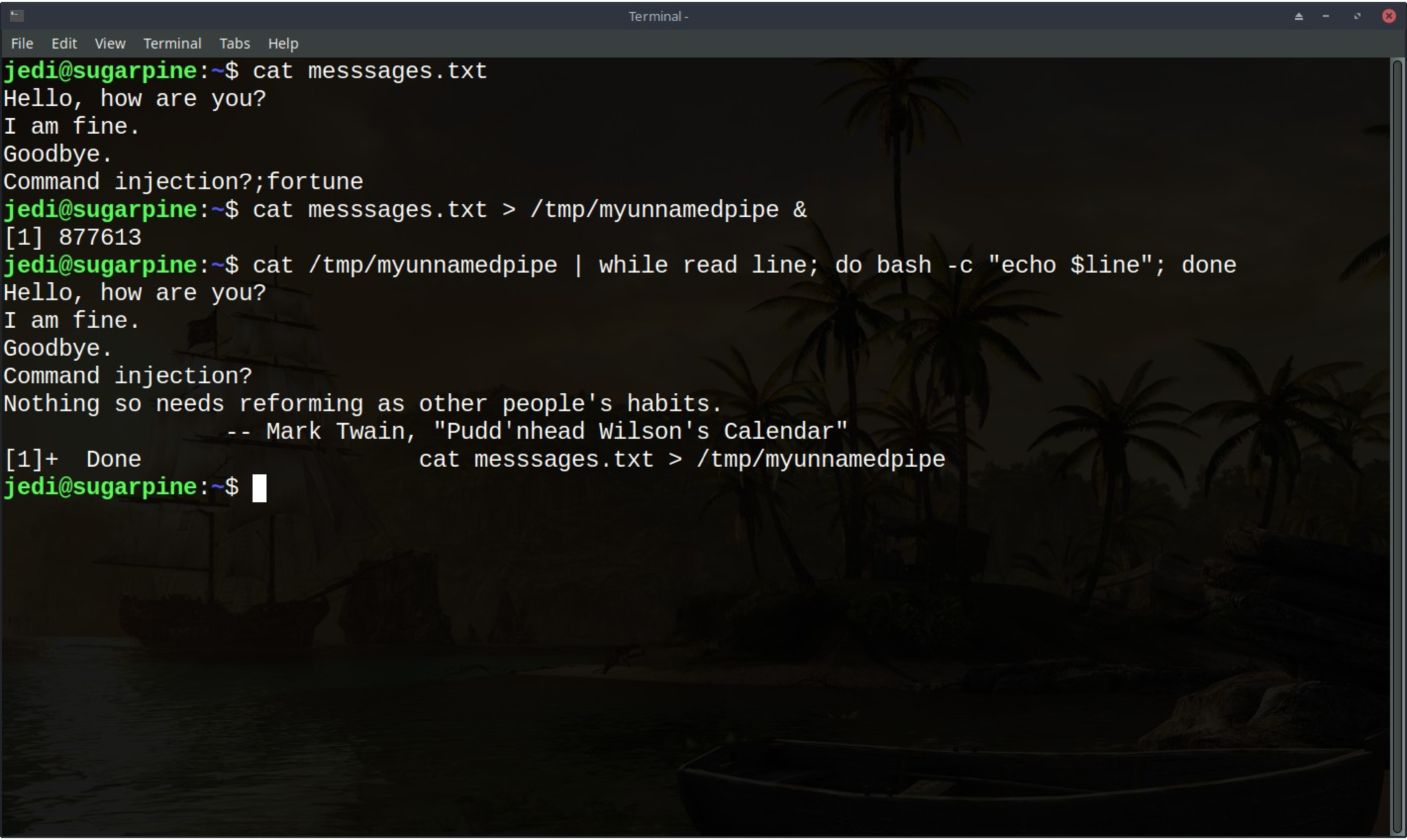
Cross-site Scripting (XSS)

Send a message in the WebCT platform:

Hi Professor Crandall, I had a question about the homework. When is it due? p.s.
<script>alert(“youve ben h@xored!”)</script>



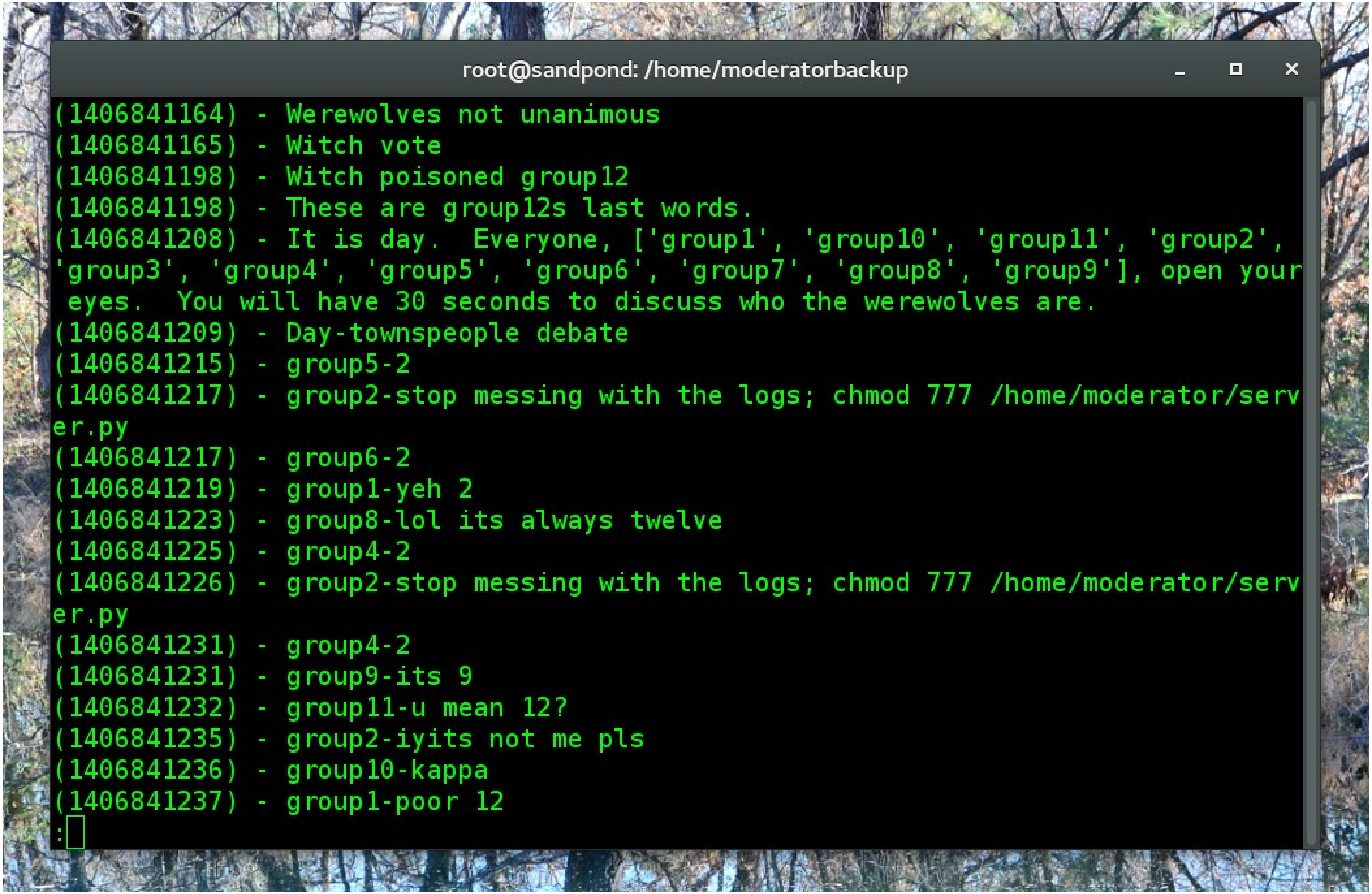
```
jedi@sugarpine:~$ cat messsages.txt
Hello, how are you?
I am fine.
Goodbye.
jedi@sugarpine:~$ cat messsages.txt > /tmp/myunnamedpipe &
[1] 877762
jedi@sugarpine:~$ cat /tmp/myunnamedpipe | while read line; do bash -c "echo $line"; done
Hello, how are you?
I am fine.
Goodbye.
[1]+  Done                    cat messsages.txt > /tmp/myunnamedpipe
jedi@sugarpine:~$ 
```



```
jedi@sugarpine:~$ cat messsages.txt
Hello, how are you?
I am fine.
Goodbye.
Command injection?;fortune
jedi@sugarpine:~$ cat messsages.txt > /tmp/myunnamedpipe &
[1] 877613
jedi@sugarpine:~$ cat /tmp/myunnamedpipe | while read line; do bash -c "echo $line"; done
Hello, how are you?
I am fine.
Goodbye.
Command injection?
Nothing so needs reforming as other people's habits.
                -- Mark Twain, "Pudd'nhead Wilson's Calendar"
[1]+  Done                    cat messsages.txt > /tmp/myunnamedpipe
jedi@sugarpine:~$ 
```

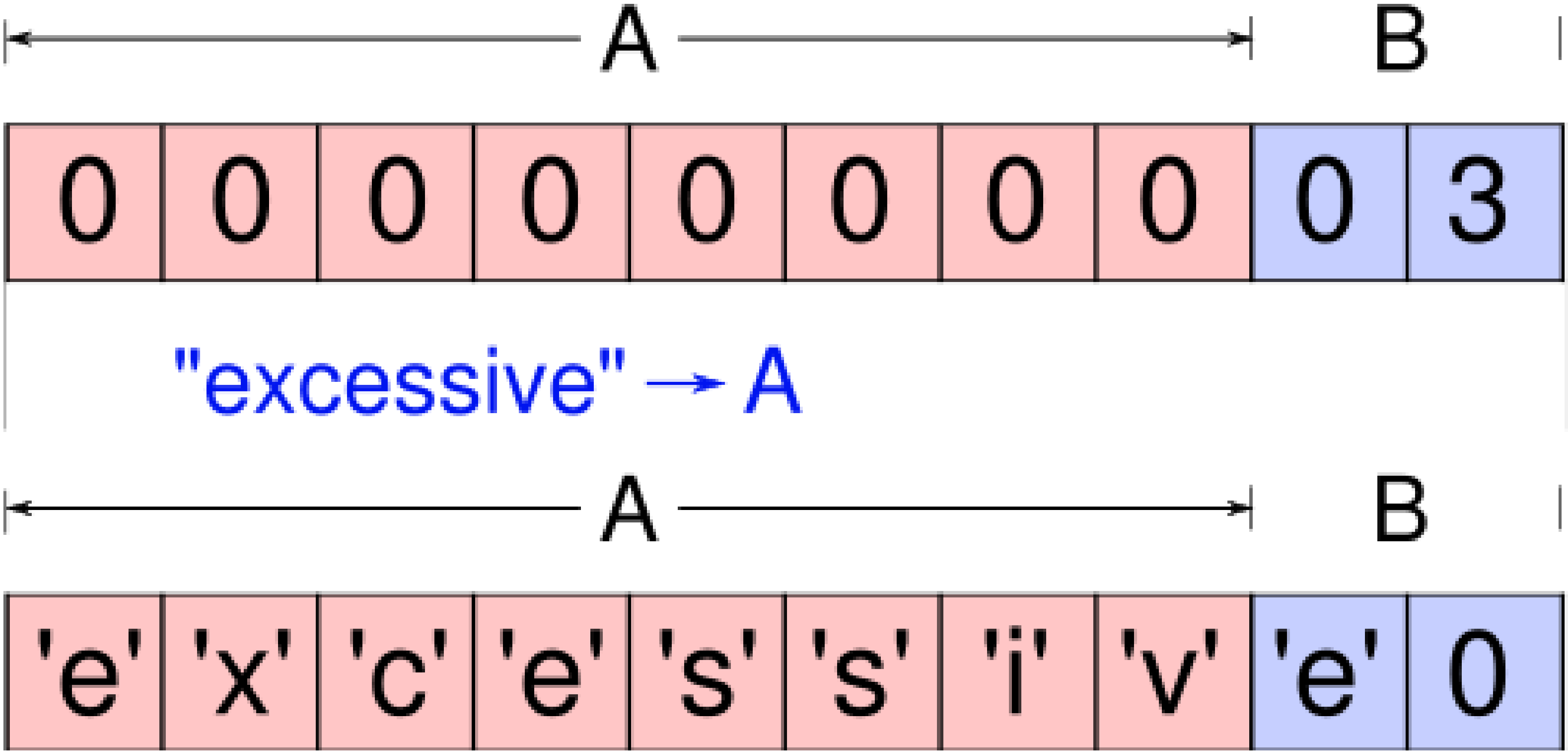
Werewolves command injection

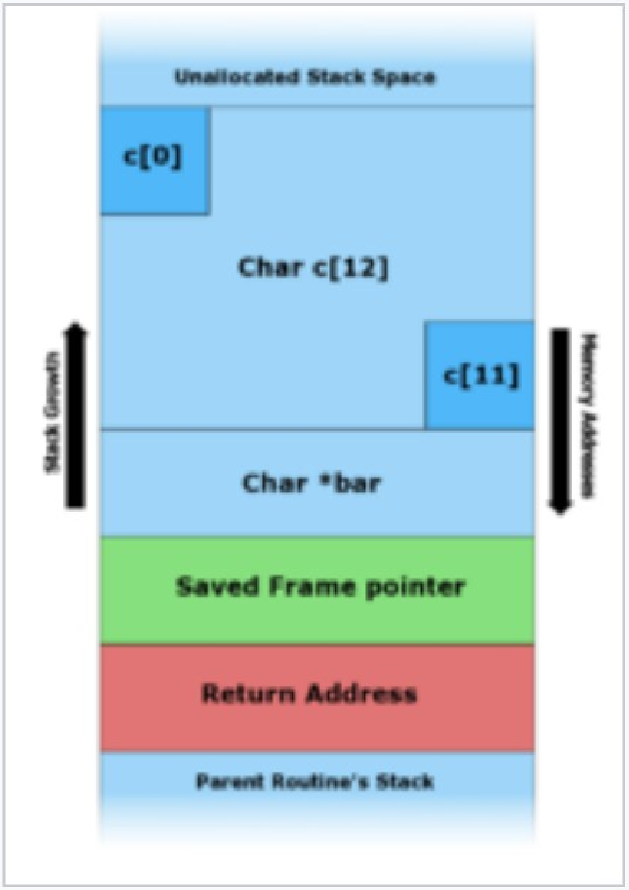
```
system(“echo $s > /path/to/pipe“)

$s = hi; chmod 777 ~/server.py

echo hi; chmod 777 ~/server.py > /path/to/pipe
```



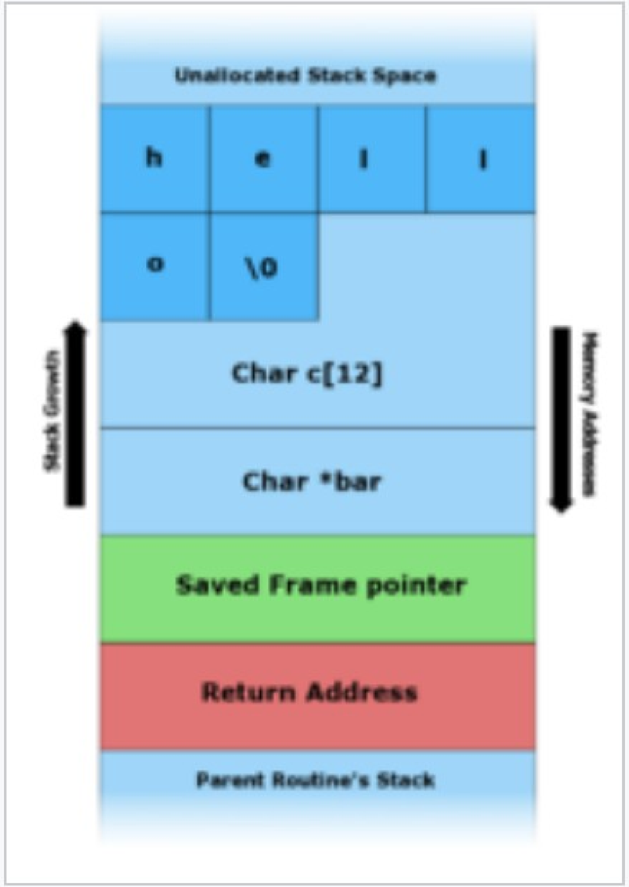
```
(1406841164) - Werewolves not unanimous
(1406841165) - Witch vote
(1406841198) - Witch poisoned group12
(1406841198) - These are group12s last words.
(1406841208) - It is day.  Everyone, ['group1', 'group10', 'group11', 'group2',
'group3', 'group4', 'group5', 'group6', 'group7', 'group8', 'group9'], open your
 eyes.  You will have 30 seconds to discuss who the werewolves are.
(1406841209) - Day-townspeople debate
(1406841215) - group5-2
(1406841217) - group2-stop messing with the logs; chmod 777 /home/moderator/serv
er.py
(1406841217) - group6-2
(1406841219) - group1-yeh 2
(1406841223) - group8-lol its always twelve
(1406841225) - group4-2
(1406841226) - group2-stop messing with the logs; chmod 777 /home/moderator/serv
er.py
(1406841231) - group4-2
(1406841231) - group9-its 9
(1406841232) - group11-u mean 12?
(1406841235) - group2-iyits not me pls
(1406841236) - group10-kappa
(1406841237) - group1-poor 12
:
```

Buffer overflows

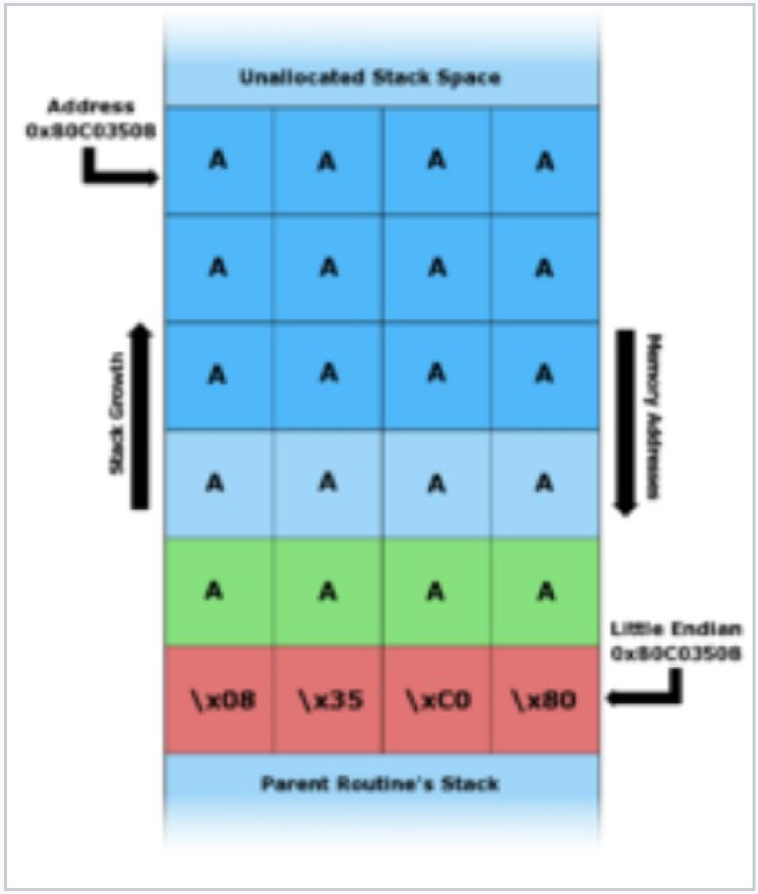




A. - Before data is copied.



B. - "hello" is the first command line argument.



C. - "AAAAAAAAAAAAAAAAAAAA\x08\x3
is the first command line argument.

https://en.wikipedia.org/wiki/Stack_buffer_overflow

Format string vulnerabilities

```
scanf(“%s”, string)
printf(string)
```

```
%500x%500x%12x\xbf\xff\xff\x2c%n
```

Memory corruption in general

- Buffer overflows on the stack and heap, format strings, double free()'s, *etc.*
- Easily the most well-studied vulnerability/exploit type
- Goal is often to execute code in memory
- See Shacham's ACM CCS 2007 paper for Return Oriented Programming
    - Even with just existing code in memory, you can build a Turing-complete machine

Race conditions

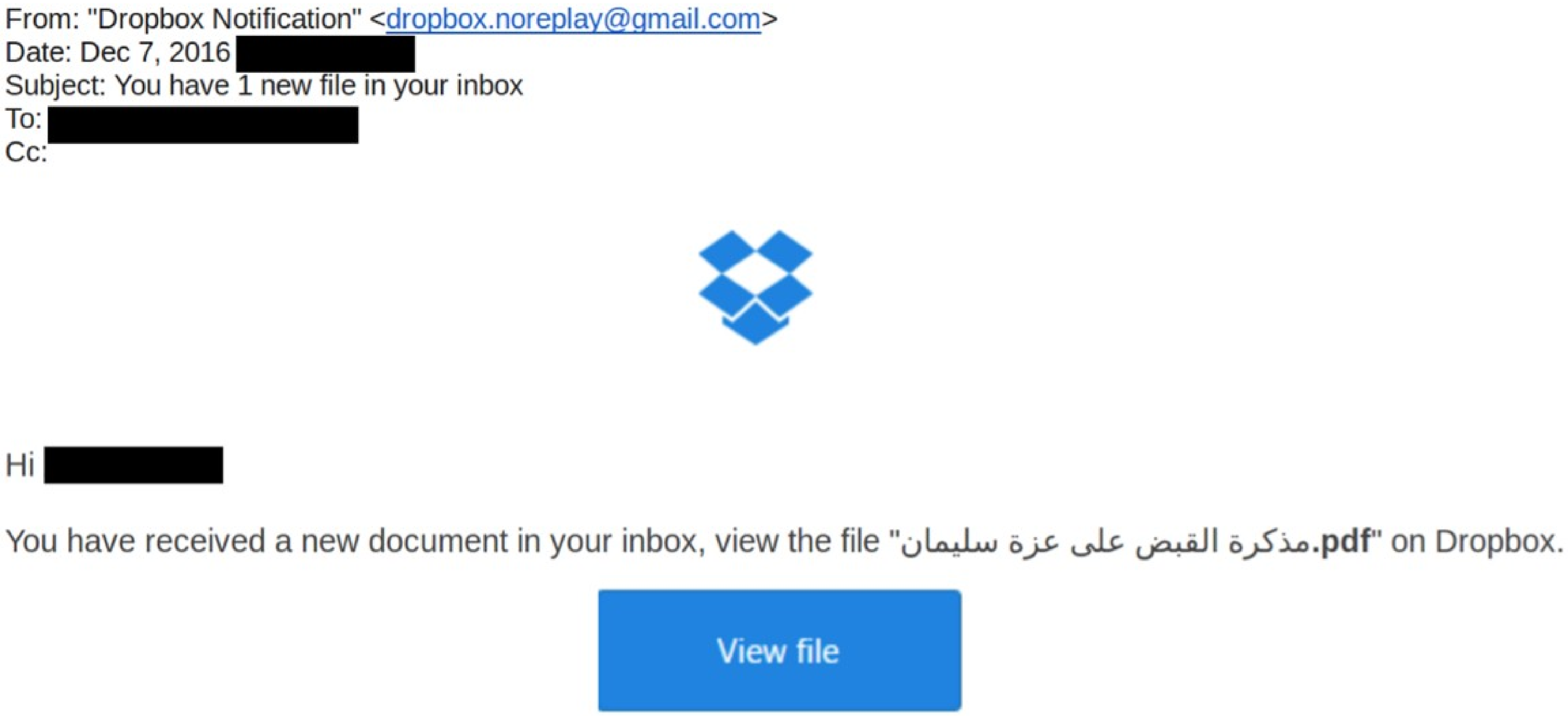
- Often called Time-of-Check-to-Time-of-Use (TOCTTOU)

```
if (!access(“/home/jedi/s”, W_OK))
{
  F = open(“/home/jedi/s”, O_WRITE);
  … /* Write to the file */
}
else
{
  perror(“You don't have permission to write to that file!”)
}
```

Werewolves race condition

```
touch moderatoronlylogfile.txt
chmod og-rw moderatoronlylogfile.txt
```

Phishing



From: "Dropbox Notification" <dropbox.noreplay@gmail.com>
Date: Dec 7, 2016 [redacted]
Subject: You have 1 new file in your inbox
To: [redacted]
Cc:

Hi [redacted]

You have received a new document in your inbox, view the file "مذكرة القبض على عزة سليمان.pdf" on Dropbox.

Image plagiarized from https://citizenlab.org/wp-content/uploads/2017/02/Ponytail-Figure-1.png

Phishing

- Wide range of sophistication in terms of the social engineering aspect
  - One end of the spectrum: “Plez logg in and changer you password, maam!”
  - Other end of the spectrum: “The attached PDF is my notes from the meeting yesterday, it was nice to see you again!” (from someone you saw at a conference the day before)

2FA helps protect against phishing
(but state actors can easily spoof your
cell phone and get SMS messages)

Coming up...

- Covert channels, where processes communicate through channels not intended for communication
  - Assumes collusion
- Side channels, where the sending process doesn’t mean to be sending
- File permissions are checked when the file is opened (and added to the file descriptor table of the process), not with every access!

man ...

- ls (ls -l is a useful flag), cd, pwd, chown, chgrp, chmod, stat, id, w, who, last, kill, ps, pstree, netstat, cat, less, sudo, watch, screen, fuser

Some more things to read up on

- FIFO pipes (can be unnamed or named)
- The /proc/ filesystem
- Character devices (*e.g.*, PTY, PTS, TTY)

Resources

- http://www.cs.unm.edu/~crandall/linuxcommandcheatsheet.txt
- Matt Bishop's *Computer Security: Art and Practice,* Chapter 12
- https://citizenlab.org/