CS 134:
Operating Systems
Process Execution

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Overview

Patch Peer Review

Programs, Memory, & Address Space

- Running a Program
- Filling Memory
- Selecting Space
- Memory Sharing

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Filling Memory
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Memory Sharing

Numeric Evaluations

Group	Clarity	Concise	Fit	Correct	Docs	Total
fax	4.22	4.78	4.56	4.11	4.67	22.34
ewes	3.67	4.67	4.67	3.67	4.33	21.01
biker	4.33	4.67	4.00	3.33	4.67	21.00
nigh	4.33	4.67	5.00	3.33	3.67	21.00
loan	3.67	4.33	4.33	3.67	4.33	20.33
eat	5.00	4.33	3.67	2.00	4.67	19.67
fakes	3.67	3.67	4.00	3.33	5.00	19.67
gates	4.33	3.33	4.00	2.33	5.00	18.99
loop	4.67	3.67	4.67	2.67	2.67	18.35
halos	3.67	3.67	3.00	4.00	4.00	18.34

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CS34
└─Patch Peer Review
└─Numeric Evaluations

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Ranking

Rank	Group
1.50	loan
1.67	fax
2.25	fakes
2.33	ewes
2.33	nigh
3.00	biker
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3.33	eat
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3.50	gates
3.50	loop

Background—How Processes Get into Memory

Class Exercise:

What transformations does the C source below need go through to become a running process?

```
int main()
{
    write(1, "Hello, world\n",  13);
    return 0;
}
```


Background—How Processes Get into Memory

Class Exercise:

What transformations does the C source below need go through to become a running process?

int main()
{
    write(1, "Hello, world\n", 13);
    return 0;
}

Assembly code—`helloworld.s`

```
.rdata
LC0:
  .ascii "Hello World\n\000"

.text
main:
  addiu sp,sp,-24 # Set up stack frame for main
  la    a1,LC0    # Params for write: a0 = 1, a1 = address
  li    a0,1      # of "Hello world" string, and a2 = 12
  sw    ra,16(sp) # Save our return address (jal overwrites)
  jal   write     # Call write
  li    a2,13     # Delay slot! Executed BEFORE instr above!
  lw    ra,16(sp) # Restore our return address
  move  v0,0      # Our return value is zero
  jr    ra        # Adjust stack and return to caller
  addiu sp,sp,24  # Delay slot! Executed BEFORE instr above!
  nop
```

Object code—`helloworld.o`

Contents of section `.text`:

```
0000 27BDFFE8 3C050000 24A50000 24040001
0010 AFBF0010 0C000000 2406000C 8FBF0010
0020 00001021 03E00008 27BD0018 00000000
```

Contents of section `.data`:

Contents of section `.rodata`:

```
% Hello World.....
  0000 48656C6C 6F2C2077 6F726C64 0A000000
```


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Contents of section .data:
Contents of section .rodata:
% Hello World.....
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The `.rodata` contains "Hello, world\n"

Object code—`helloworld.o`

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    27BDFFE8  addiu  sp,sp,-24
    3C050000  lui    a1,0
    24A50000  addiu  a1,a1,0
    24040001  li     a0,1
    AFBF0010  sw     ra,16(sp)
    0C000000  jal    0
    2406000C  li     a2,12
    8FBF0010  lw     ra,16(sp)
    00001021  move   v0,0
    03E00008  jr     ra
    27BD0018  addiu  sp,sp,24
    00000000  nop
```


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CS34
└Programs, Memory, & Address Space
└Running a Program
└Object code—helloworld.o

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0010 AFBF0010 0C000000 2406000C 8FBF0010
0020 00001021 03E00008 27BD0018 00000000
```

Relocation records for section `.text`:

	Type	*Value*
0004	R_MIPS_HI16	.rodata
0008	R_MIPS_LO16	.rodata
0014	R_MIPS_26	write

Object code—helloworld.o
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Executable code—`helloworld`

Link with `libc.a` and `crt0.o`

- `crt0.o` contains startup code
- `libc.a` contains code for `write`
  - Note no dynamic/shared library support yet!
- Linker can resolve the relocation entries
- End result is an executable, or *load image*.

The OS still needs to:

- Decide if it has resources to run the program right now (long-term scheduler)
- Decide where to put the program in memory
- Perform any additional setup
- Start executing the program

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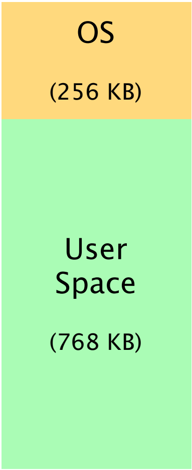
Uniprogramming OS

Only one process—can always locate running process in same place

- Static linking
- Loading is easy

Class Exercise

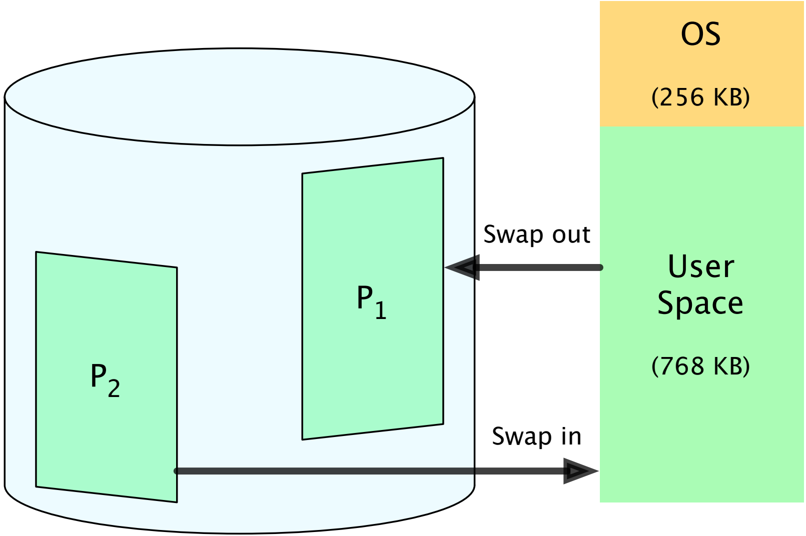
What is the *easiest* way to retrofit this model to run a second program when the first one has to wait for a while?



Uniprogramming OS
Only one process—can always locate running process in same place
Static linking
Loading is easy
Class Exercise
What is the easiest way to retrofit this model to run a second program when the first one has to wait for a while?
OS (256 KB) User Space (768 KB)

Simple Multiprogramming, using Swapping

Add swapping to uniprogramming OS:



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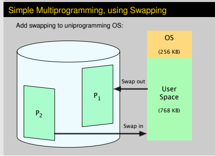
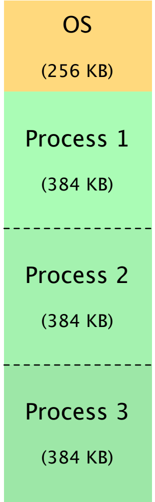
└Programs, Memory, & Address Space
  └Filling Memory
    └Simple Multiprogramming, using Swapping



Fixed Partitioning

Add more memory, to allow multiple processes



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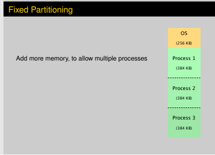
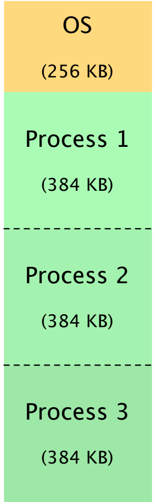


Fixed Partitioning

Add more memory, to allow multiple processes

But

- Processes don't have a fixed address in memory
- Loading must deal with relocation?



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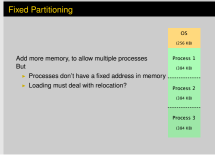
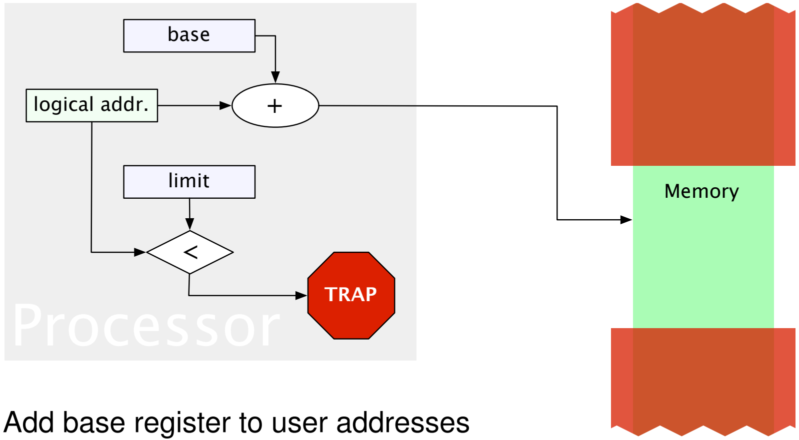


Runtime Relocation—Hardware to the rescue

Remember when we talked about protection?



Add base register to user addresses

- *Logical address*—used by program
- *Physical address*—actual address in physical memory

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CS34
└Programs, Memory, & Address Space
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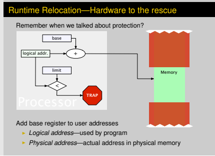
  └Runtime Relocation—Hardware to the rescue



Runtime Relocation—Software alternative

Position-independent code: either

- Grab a register to use as our “base” register and add or subtract from that, or
- Calculate address based on current program counter

Runtime Relocation—Software alternative
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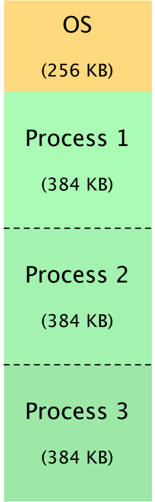
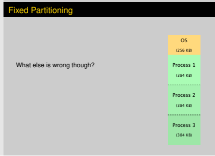
Fixed Partitioning

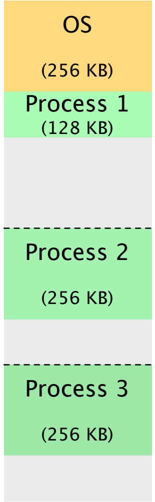
What else is wrong though?





Fixed Partitioning

Some programs need less memory than others. . .



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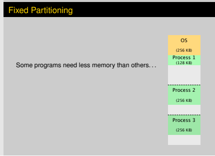
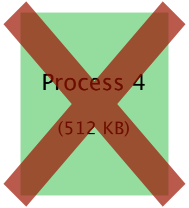
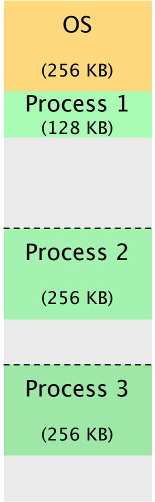


Fixed Partitioning

Some programs need less memory than others…

And some need more…





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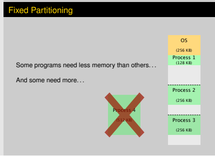
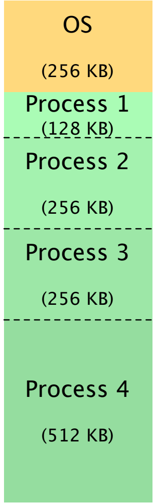


Dynamic Partitioning

Variable-sized partitions solve the problem



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CS34
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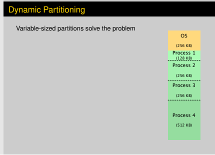
  └─Filling Memory
    └─Dynamic Partitioning



Dynamic Partitioning

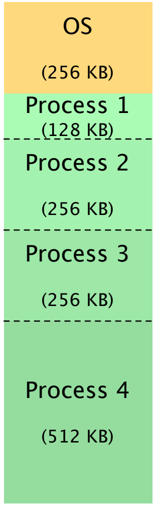
Variable-sized partitions solve the problem

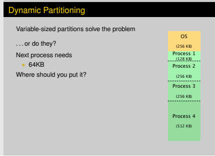
. . . or do they?

Next process needs

- 64KB

Where should you put it?





Dynamic Partitioning

Variable-sized partitions solve the problem

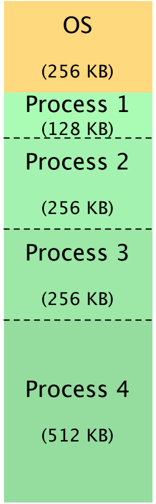
. . . or do they?

Next three processes need

- 64KB
- 64KB
- 256 KB

Or perhaps next four processes need

- 64KB
- 96 KB
- 96 KB
- 128 KB



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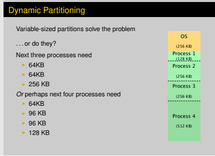
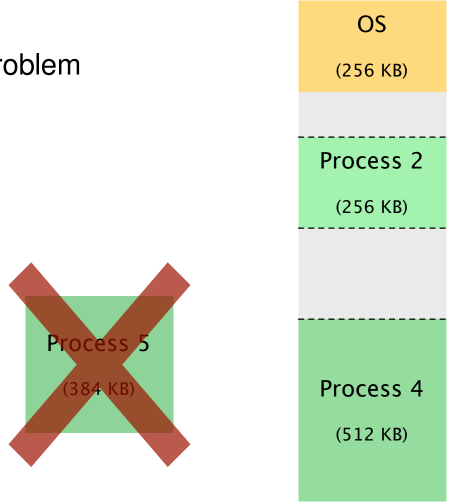


Dynamic Partitioning

Dynamic partitions solve the problem

... or do they?

Next process needs
- 384 KB



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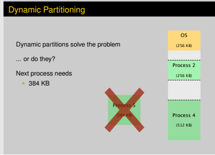

Which Hole?

Best fit?

- Choose smallest hole that is large enough

Worst fit?

- Choose largest hole that is large enough

First fit?

- Choose first hole that is large enough

Next fit?

- Choose first hole that is large enough, starting search after last hole we allocated from

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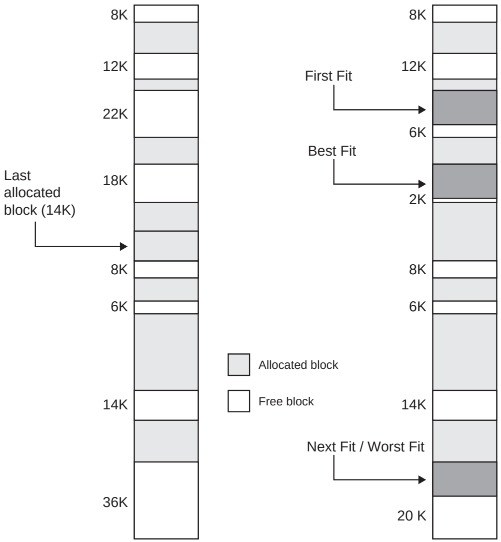
Which hole?

Class Exercise

Which method is best?



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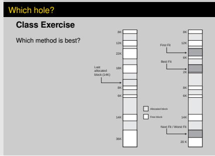
CS34
Programs, Memory, & Address Space
Selecting Space
Which hole?



External Fragmentation

All methods are prone to fragmentation

- Best fit and first fit have least fragmentation on average

Class Exercise

How can we avoid external fragmentation?

External Fragmentation
All methods are prone to fragmentation
Best fit and first fit have least fragmentation on average
Class Exercise
How can we avoid external fragmentation?

Can eliminate fragmentation by *compaction*

Wasted Memory...?

What if two people are running the same editor?

Wasted Memory...?

What if two people are running the same editor?

Segments

We could introduce *segments*—code and data:

- Program code is put in a *program segment* (read only), shared between processes
- Program data is put in a *data segment*, unique to each process

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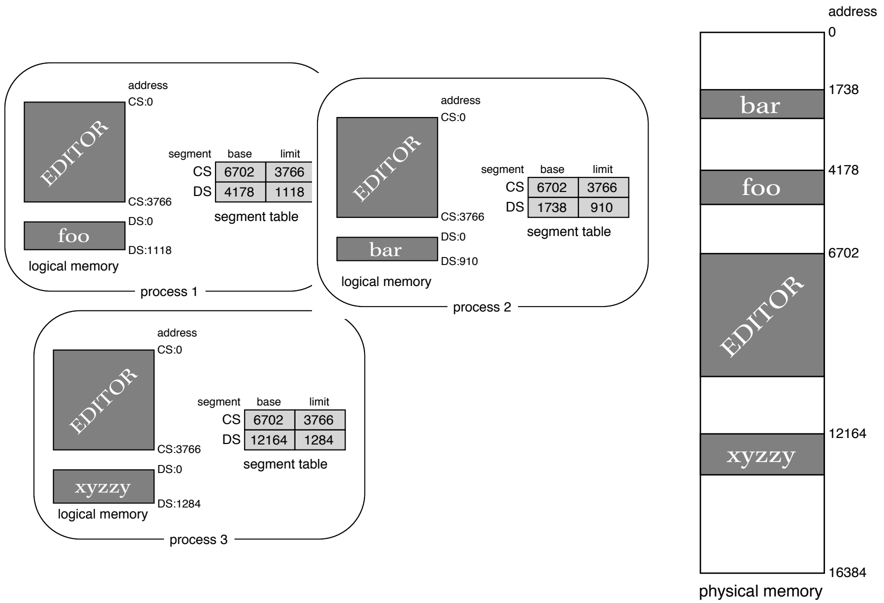

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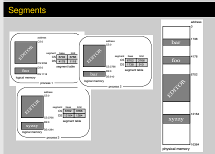
CS34
└Programs, Memory, & Address Space
  └Memory Sharing
    └Segments



More Segments

If two segments are a good idea, would more be even better?

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How about...

- A stack segment?

Class Exercise

Any other segments that might be nice to have?

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(The x86 has `CS`, `DS`, `SS` and `ES`)

More Segments
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More Segments

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How about...

- A stack segment?
- A shared-data segment?
- A heap segment?
- A segment for the C library
- A thread-local storage segment
- A bonus segment?

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CS34
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  └─Memory Sharing
    └─More Segments

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The x86 has `CS`, `DS`, `SS`, `ES`, plus `FS` and `GS`.

Problems?

More Segments
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A segment for the C library
A thread-local storage segment
A bonus segment?
The x86 has CS, DS, SS, ES, plus FS and GS.
Problems?

Confused programmers!

- Given a 32-bit address, it's hard to know which segment it points into

Are six segments enough?

Segmentation Architecture

Logical address consists of the pair

<segment-number, offset>

Example

Use 32-bit logical address

- High-order 8 bits are segment number
- Low-order 24 bits are offset within segment

256 segments, of max size 16,777,216 bytes (16MB)

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Segmentation Architecture—Segment Table

Processor needs to map 2D user-defined addresses into 1D physical addresses.
In *segment table*, each entry has:

- *Base*—Starting address of the segment in physical memory
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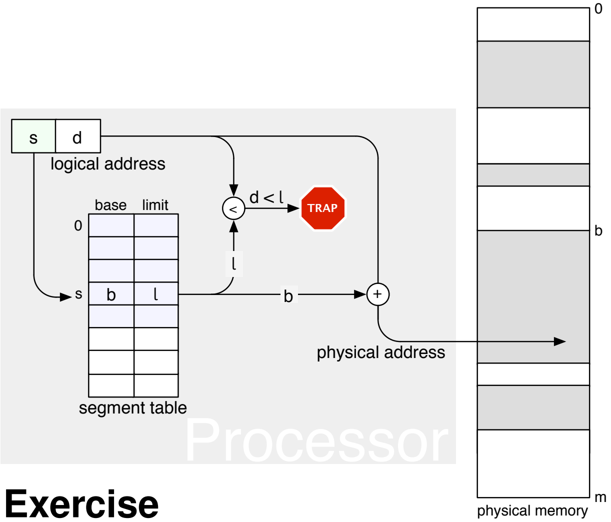
Segment Table



Class Exercise

What are the practical limits on the number of segments?

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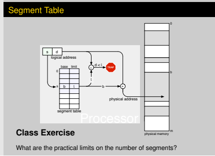

Segmentation Architecture

Design Issues:

- Relocation
  - Dynamic
  - By segment table
- Sharing
  - Shared segments
  - Same segment number
- Allocation
  - First fit/best fit
  - External fragmentation

Class Exercise

Do shared segments *need* to have the same segment number?

- If so, why?
- If not, why? (And why might we give them the same segment number anyway?)

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Segmentation Architecture

Class Exercise

Does our segmentation scheme capture the *difference* between code and data segments?

- If not, what would we need to fix it?

Class Exercise

What if a program wants more contiguous data space than a segment can hold? Is this a problem?

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Class Exercise
What if a program wants more contiguous data space than a segment can hold? Is this a problem?

With each entry in segment table, associate:

- Validation bit—0 => illegal segment
- Read/write/execute privileges
- Protection bits associated with segments; code sharing occurs at segment level

Segmentation Architecture—Fragmentation

Class Exercise

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What's the cause of the fragmentation?

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