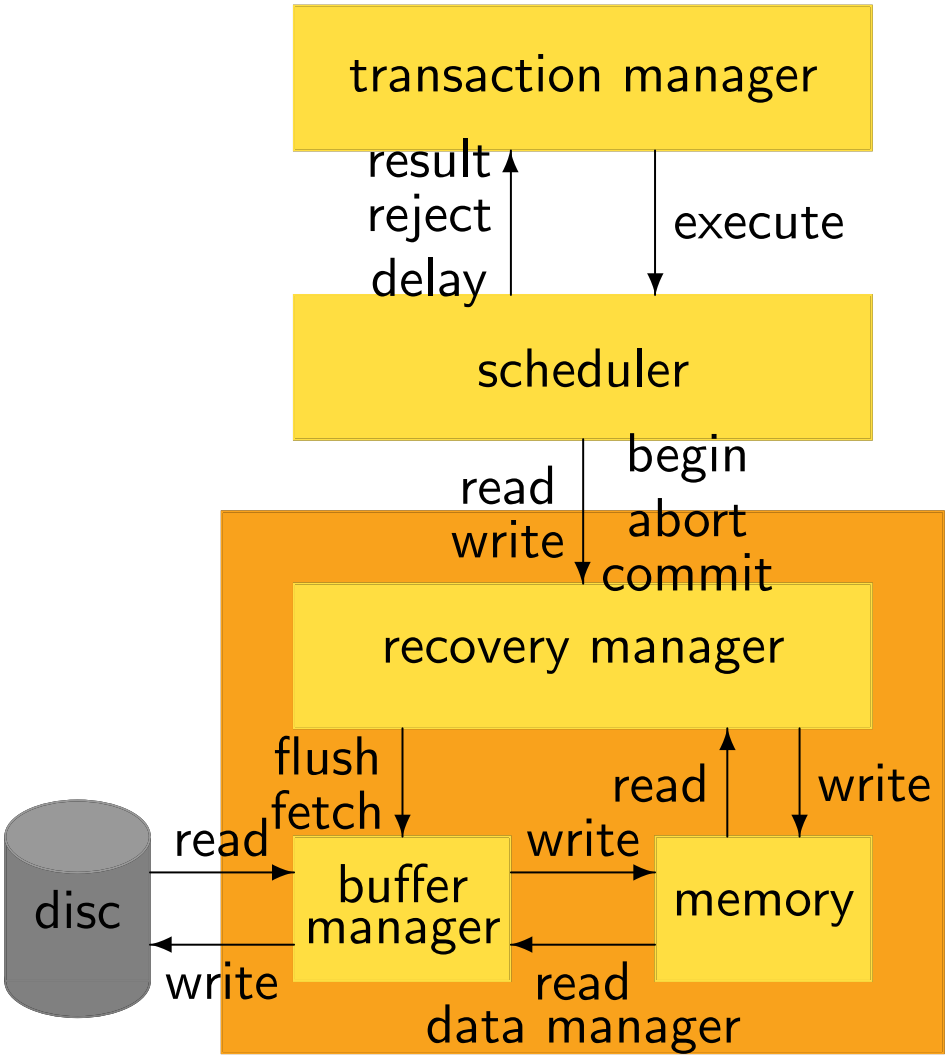
Recovery

P.J. McBrien

Imperial College London

DBMS Architecture

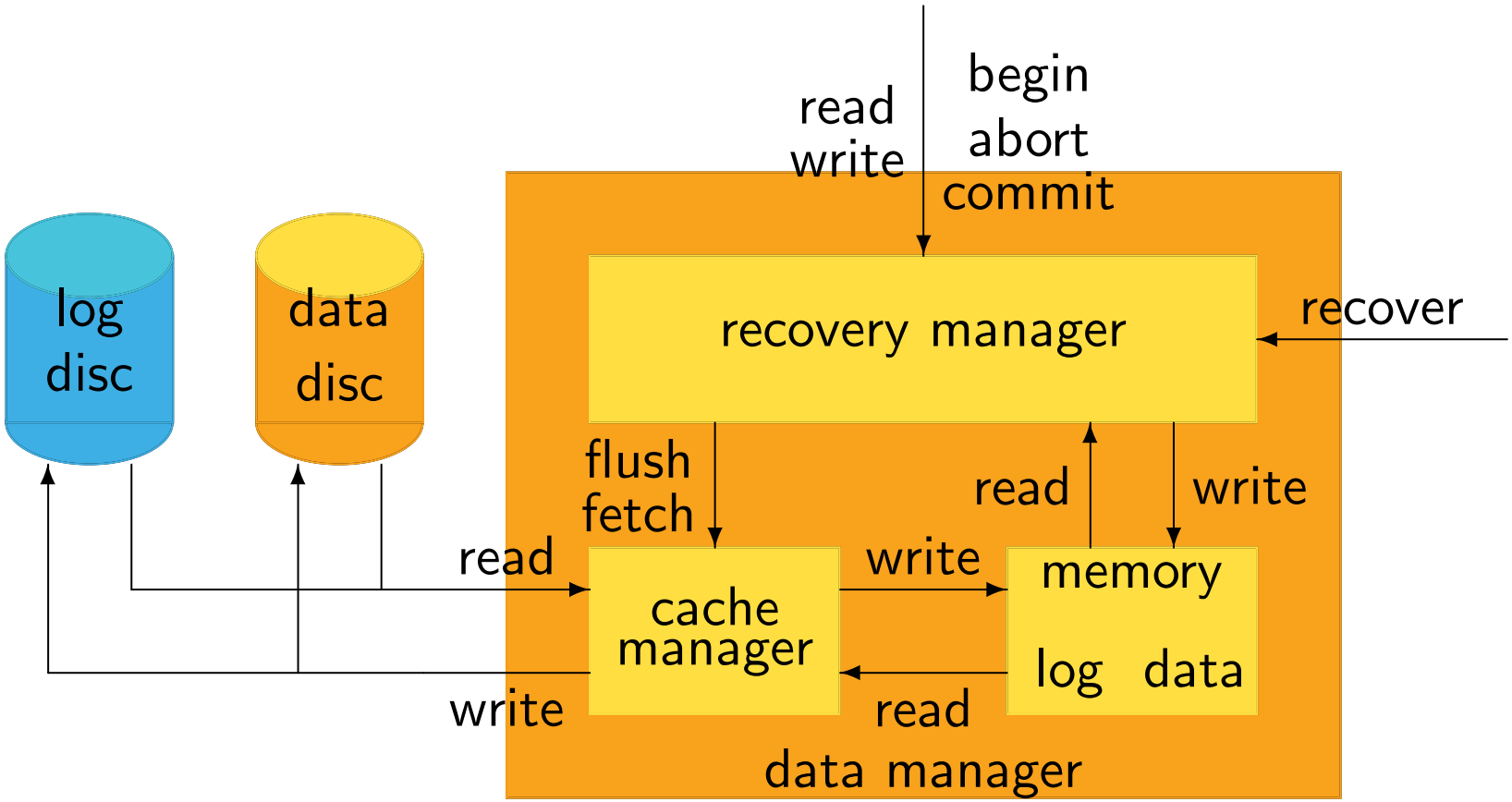


Recovery Manager (RM)

protect the DBMS against failures

- **system failures** loss of volatile storage
  1. committed transactions written to disc
  2. uncommitted transactions not written to disc
     OR
  3. sufficient information such that (1) and (2) may be met by a *recovery*
- **media failures** loss of stable storage

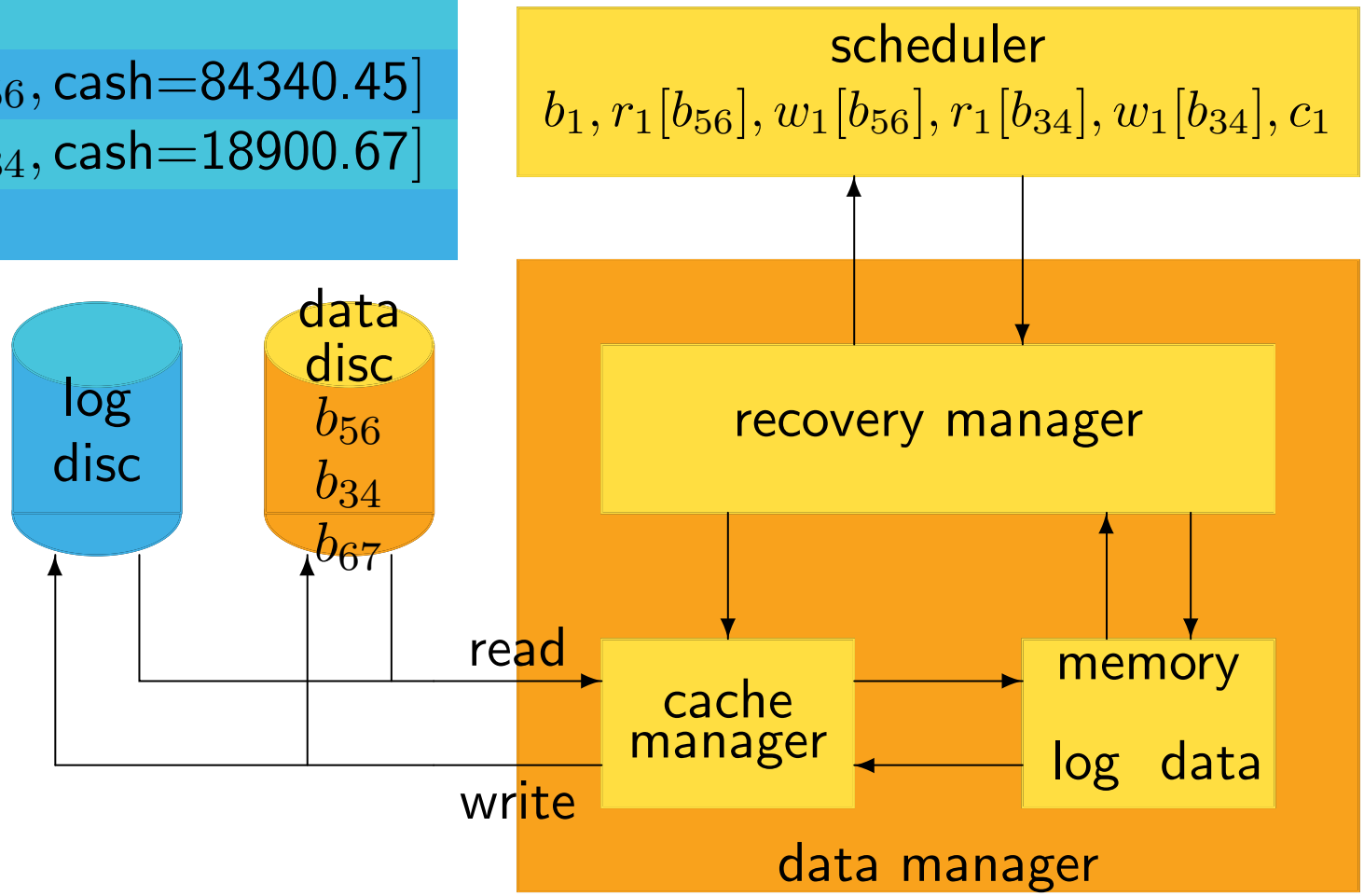
Enhanced Data Manager Architecture



- Need to cache log as well

Need to REDO

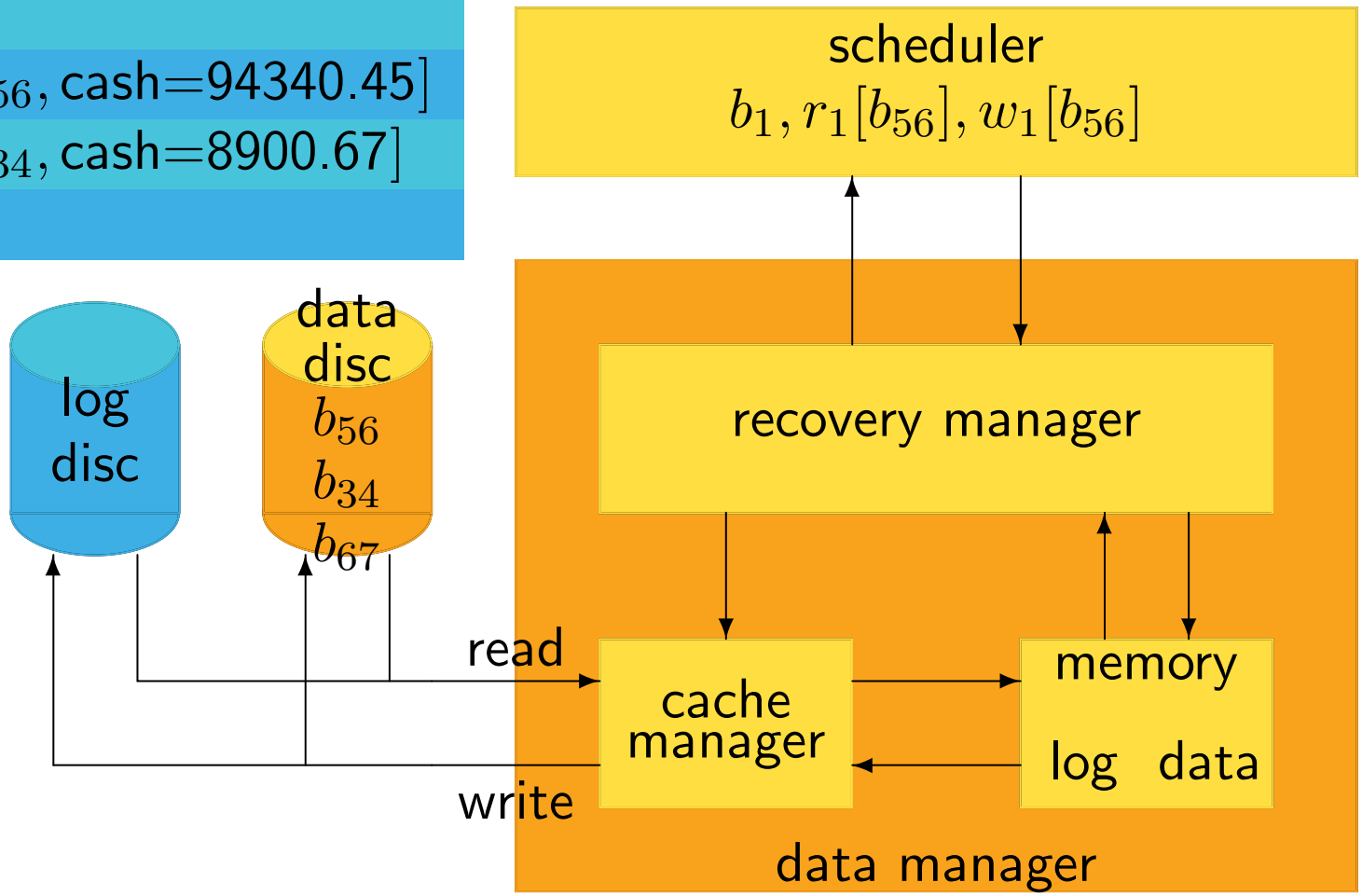
LOG	b_1
REDO	$w_1[b_{56}, \text{cash}{=}84340.45]$
REDO	$w_1[b_{34}, \text{cash}{=}18900.67]$
LOG	c_1



- REDO required if committed transactions not in stable storage
- must write all REDO to log before commit of transaction

Need to UNDO

LOG	b_1
UNDO	$w_1[b_{56}, \text{cash=94340.45}]$
UNDO	$w_1[b_{34}, \text{cash=8900.67}]$
LOG	c_1



- UNDO required if non-committed transactions in stable storage
- Must flush UNDO to log before corresponding write to data

Quiz 1: Contents of Data Disc After a Transaction

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
    UPDATE branch
    SET cash=cash-10000.00
    WHERE sortcode=56

    UPDATE branch
    SET cash=cash+10000.00
    WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ②		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

branch ③		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ④		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must the contents of the **branch** table on the data disc be after the transaction commits?

A: ④

B: ① or ④

C: ①, ③ or ④

D: ①, ②, ③ or ④

Quiz 2: Contents of Log Disc After a Transaction

Data Disc Before Transaction

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

      UPDATE branch
      SET cash=cash+10000.00
      WHERE sortcode=34
COMMIT TRANSACTION T1
```

Data Disc At Commit Time

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must be on the log disc after commit time?

A

REDO r_{56}
REDO r_{34}
UNDO r_{56}
UNDO r_{34}

B

REDO r_{56}
UNDO r_{34}

C

UNDO r_{34}

D

REDO r_{56}

Before and after images

before image

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

$\Downarrow$

$w_1[b_{56}]$

$\Downarrow$

branch		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

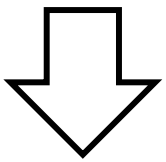
after image

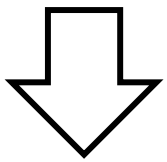
- before image allows RM to **undo** $w_1[b_{56}]$
- after image allows RM to **redo** $w_1[b_{56}]$

Database Logs

LOG	b_1
REDO	$w_1[b_{56}, \text{cash=84340.45}]$
REDO	$w_1[b_{34}, \text{cash=18900.67}]$
LOG	c_1

LOG	b_1
UNDO	$w_1[b_{56}, \text{cash=94340.45}]$
UNDO	$w_1[b_{34}, \text{cash=8900.67}]$
LOG	c_1





LOG	b_1
UNDO	$w_1[b_{56}, \text{cash=94340.45}]$
REDO	$w_1[b_{56}, \text{cash=84340.45}]$
UNDO	$w_1[b_{34}, \text{cash=8900.67}]$
REDO	$w_1[b_{34}, \text{cash=18900.67}]$
LOG	c_1

What must a complete REDO/UNDO log contain?

Must contain

- REDO information for each update
- UNDO information for each update
- commit of each transaction

Might contain

- begin of each transaction
  - can be inferred from first REDO/UNDO
  - presence useful to stop search of UNDO records
- abort of each transaction
  - can be inferred from lack of commit
  - presence useful to indicate UNDO already done

Rules for log and data updates

write ahead logging (WAL)

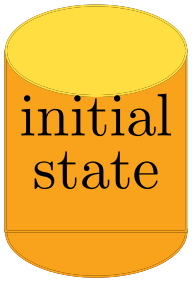
Redo rule

- commit → flush log of transaction to disc
- never respond to scheduler before log written

Undo rule:

- flushing uncommitted data → flush log of operations

Basic Recovery Procedure



$$\Rightarrow w_v[o_1], c_v, w_x[o_2], w_y[o_1], c_y, w_z[o_2] \Rightarrow$$

1. UNDO $\rightarrow$ *Scan back through the log*
   - Collect set of committed transactions $C = \{v, y\}$
   - Collect set of incomplete transactions $I = \{x, z\}$
   - Perform UNDO for any transaction in $I = w_z[o_2], w_x[o_2]$
2. REDO $\rightarrow$ *Scan forward through the log*
   - Perform REDO for any transaction in $C = w_v[o_1], w_y[o_1]$

$$\Rightarrow \text{UNDO}(w_z[o_2]), \text{UNDO}(w_x[o_2]), \text{REDO}(w_v[o_1]), \text{REDO}(w_y[o_1]) \Rightarrow$$

Example of Recovery

Log

LOG	b_4
LOG	b_1
UNDO	$w_1[b_{56}, \text{cash}{=}94340.45]$
REDO	$w_1[b_{56}, \text{cash}{=}84340.45]$
LOG	b_2
UNDO	$w_2[b_{34}, \text{cash}{=}10900.67]$
REDO	$w_2[b_{34}, \text{cash}{=}8900.67]$
UNDO	$w_2[b_{67}, \text{cash}{=}34005.00]$
REDO	$w_2[b_{67}, \text{cash}{=}36005.25]$
LOG	b_7
LOG	c_2
UNDO	$w_1[b_{34}, \text{cash}{=}8900.67]$
REDO	$w_1[b_{34}, \text{cash}{=}18900.67]$
UNDO	$w_7[b_{67}, \text{cash}{=}36005.25]$
REDO	$w_7[b_{67}, \text{cash}{=}37005.25]$
LOG	c_7
LOG	c_4

Disc Before Recovery

branch		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

Disc After Recovery

branch		
sortcode	bname	c
56	'Wimbledon'	00000.0094340
34	'Goodge St'	8900.678900
67	'Strand'	36005.2537005

Omitting the REDO Log

If no REDO records kept

must flush committed transactions to data disc

1. $C = \emptyset, D = \emptyset$
2. Scan the log backwards from the end.
3. commit entry $\rightarrow$ add to C
4. undo entry for member of $C \rightarrow$ add object to D *without* making changes to the data.
5. perform undo entry for object not of member D

Omitting the Undo Log

If no UNDO records kept

transaction must never write uncommitted data

- add **fix** command between RM and CM to stop CM flushing data
- commit is followed by flush or **unfix** of fixed objects

Omitting UNDO and REDO

atomic commit $\rightarrow$ out of place updating

Quiz 3: Contents of Disc Before Commit if no UNDO log

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

      UPDATE branch
      SET cash=cash+10000.00
      WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①		
sortcode	bname	cash
56	'Wimbledon'	94340.45
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branch ②		
sortcode	bname	cash
56	'Wimbledon'	94340.45
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67	'Strand'	34005.00

branch ③		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ④		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must the contents of the branch table on disc be before the transaction commits?

A: ①

B: ① or ④

C: ④

D: ①,②,③ or ④

Quiz 4: Contents of Disc After Commit if no REDO log

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

      UPDATE branch
      SET cash=cash+10000.00
      WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ②		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

branch ③		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ④		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must the contents of the branch table on disc be after the transaction commits?

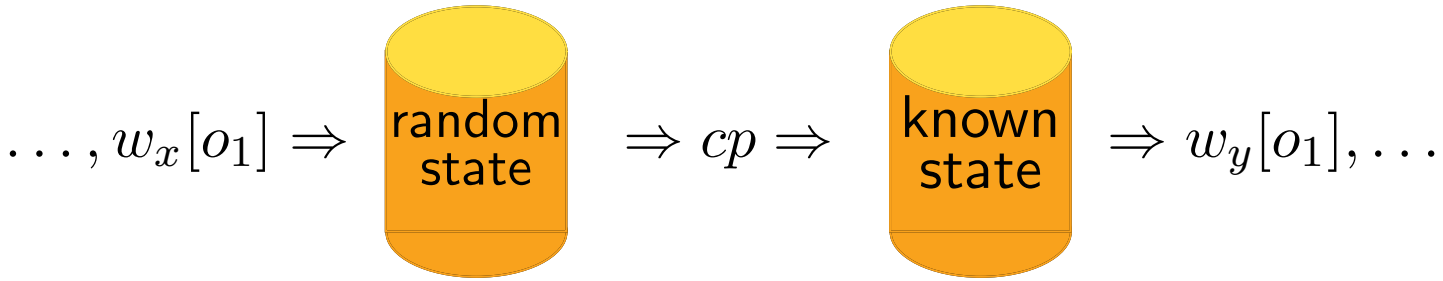
A: ①

B: ① or ④

C: ④

D: ①,②,③ or ④

Checkpointing



- Forces the database into some known state
- Recovery limited to only look back to checkpoint (or a 'bit' before!)
  - speeds the recovery operation
  - limits the size of log
- The more consistent this known state
  - the easier it is to recover
  - the longer it takes to perform the checkpoint

Commit Consistent Checkpoint

Generating a Commit Consistent Checkpoint

1. Stop accepting new transactions
2. Finish existing transactions.
3. Flush all dirty data cache objects to disc.
4. Write a checkpoint to stable log.

- recovery now only needs to scan back to *cp* in log ✔
- possible long hold-up at checkpoint ✖

Cache Consistent Checkpoint

Generating a Cache Consistent Checkpoint

1. Suspend all transactions
2. Flush all dirty cache objects to disc
3. Write a checkpoint + active transactions to stable log

Recovery from Cache Consistent Checkpoint records

1. perform UNDOs of non-committed transactions back to *cp*
2. perform UNDO of non-committed transactions before *cp* if they were active at *cp*
3. perform REDOs of committed transactions after *cp*

- could still have delay whilst flushing cached objects

Worksheet: Cache Consistent Checkpoint

LOG	b_7
UNDO	$w_7[b_{67}, \text{cash=}34005.25]$
REDO	$w_7[b_{67}, \text{cash=}37005.25]$
LOG	b_2
UNDO	$w_2[b_{34}, \text{cash=}10900.67]$
REDO	$w_2[b_{34}, \text{cash=}8900.67]$
LOG	b_6
UNDO	$w_6[a_{101}, \text{rate=}5.25]$
REDO	$w_6[a_{101}, \text{rate=}6.00]$
LOG	b_1
UNDO	$w_1[b_{56}, \text{cash=}94340.45]$
REDO	$w_1[b_{56}, \text{cash=}84340.45]$
LOG	a_7
LOG	$cp\{1, 2, 6\}$
	$\vdots$

	$\vdots$
UNDO	$w_6[a_{119}, \text{rate=}5.50]$
REDO	$w_6[a_{119}, \text{rate=}6.00]$
LOG	c_6
UNDO	$w_2[b_{67}, \text{cash=}34005.00]$
REDO	$w_2[b_{67}, \text{cash=}36005.25]$
LOG	b_8
LOG	c_2
UNDO	$w_1[b_{34}, \text{cash=}8900.67]$
REDO	$w_1[b_{34}, \text{cash=}18900.67]$
LOG	b_9
UNDO	$w_9[b_{67}, \text{cash=}36005.00]$
REDO	$w_9[b_{67}, \text{cash=}20000.00]$
LOG	c_9

Fuzzy Checkpointing

Generating a Fuzzy Checkpoint

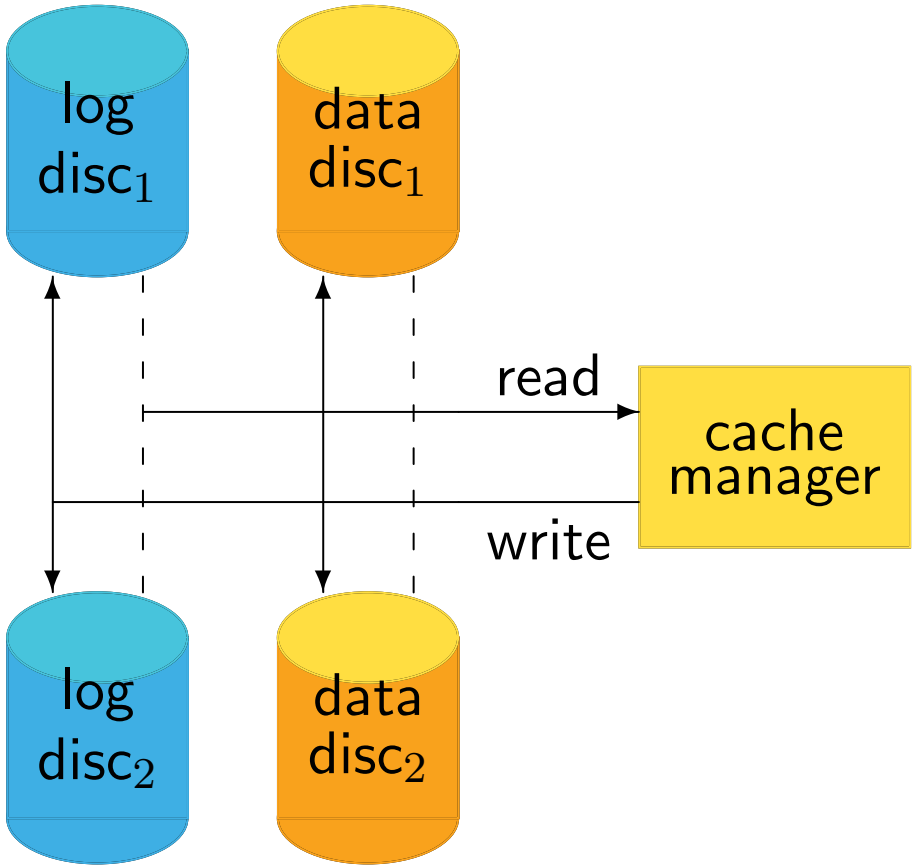
1. Suspend all transactions
2. Flush any dirty cache objects to disc not flushed in previous *cp*
3. Write a checkpoint + active transactions to stable log

Recovery from Fuzzy Checkpoint records

Recovery works like cache consistent checkpoint, but working with penultimate *cp*

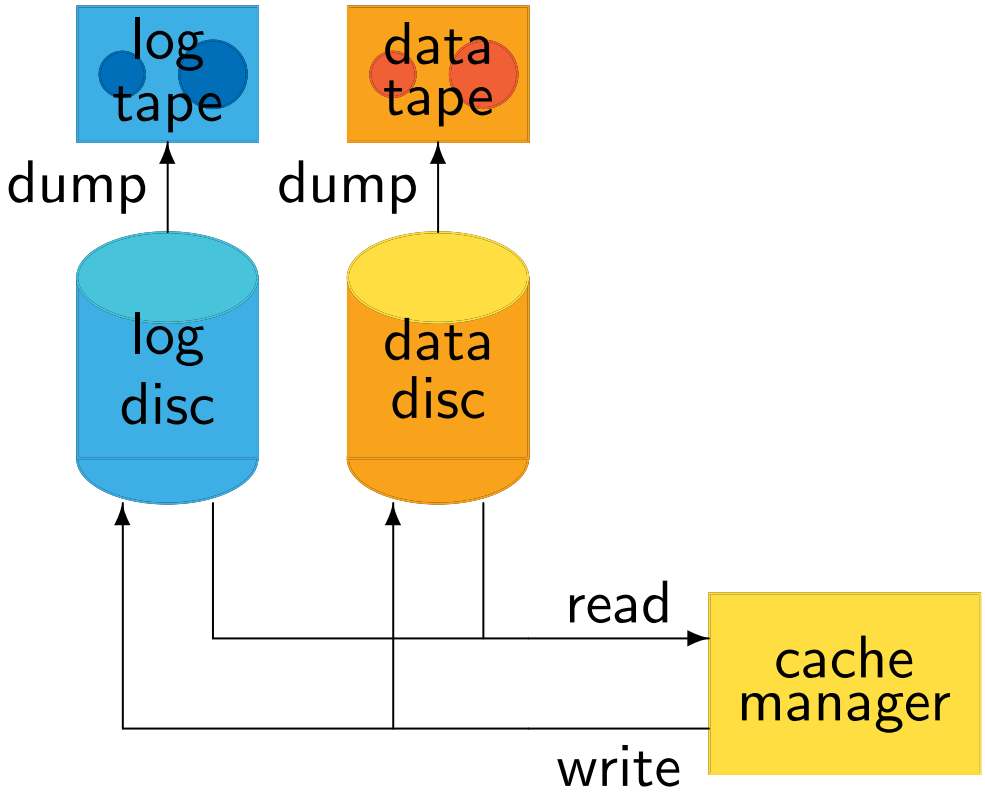
1. perform UNDOs of non-committed transactions back to penultimate *cp*
2. perform UNDO of non-committed transactions before penultimate *cp* if they were active at *cp*
3. perform REDOs of committed transactions after penultimate *cp*

Media Failures: Mirroring (RAID-1)



- Keep more than one active copy of data and log
- Writes sent to both
- Read from either

Media Failures: Dumping

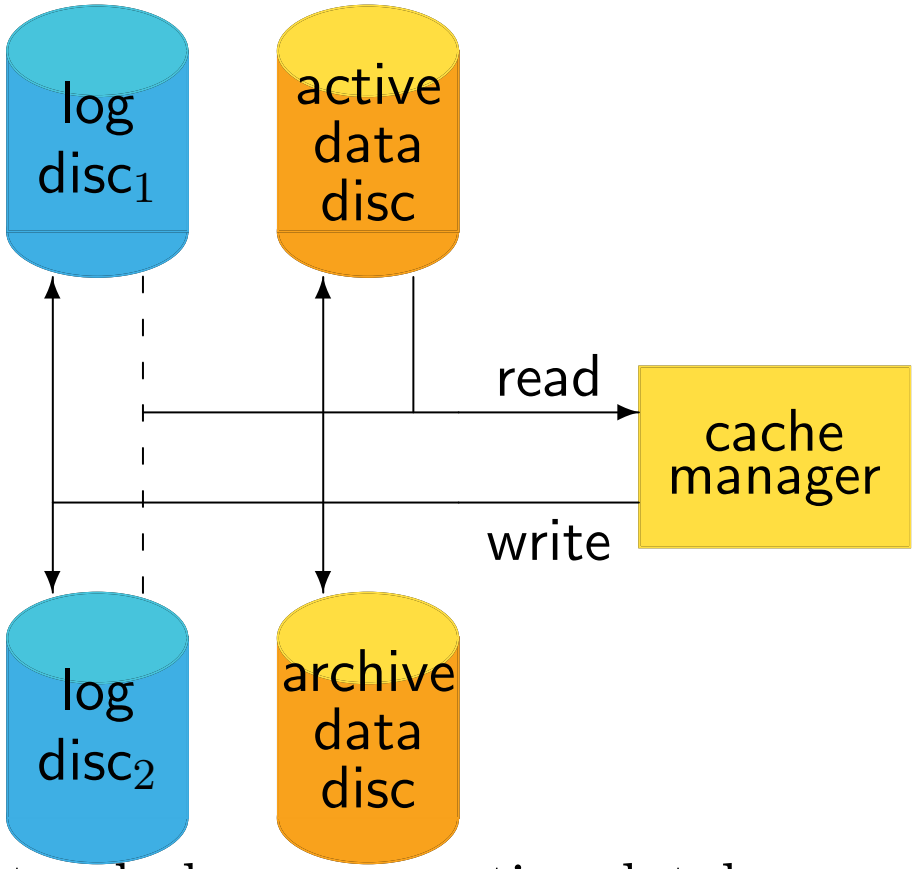


- 'tape' might also be a external file server, removable HD, *etc.*
- To use normal OS backup procedure
  - DBMS must not be still running
  - raw partition must not be used

Checkpoints and Dumps

- Dump must do a checkpoint
- Restore involves:
  1. copy tape to disc
  2. undo transactions active at the archive time
  3. redo transactions that committed after the archive
- commit consistent checkpoint obvious choice

Media Failures: Archive Database



- mirror log, but only have one active database
- periodically archive updates onto archive database
- failure of active database disc involves restore of archive database using logs

THE END

- Content of the course is what has been presented in the lectures
- Revise by reviewing worksheets and courseworks
- 2011 exam papers onwards set to current syllabus
- Older exam questions mostly apply, but there is more emphasis on RA and SQL, less on concurrency.