Today
- Volatile storage
- RAID.
- Concurrency control
  - How transactions cope with living together:
    - Serializability
    - Locking
    - Optimistic concurrency control

The need for volatile storage
- DB systems often store data of large value.
- Losing data is unacceptable (consider e.g. the account information in a bank).
- We need storage that is very robust.
- Problem: Single disks may fail because of head crashes, fire, explosions, etc.

MEDIA FAILURES
Lecture based on [GUW, 11.6-11.7]

Can’t get 100% guarantee
- No matter how data is stored, we can’t make it 100% safe.
- However, the probability of losing it can be made negligible, e.g., 10^{-10}/year.
- The basic idea is to introduce redundancy such that all data can be recovered even if part of what is stored is lost.

Duplication
- A simple solution is to make one or more copies (mirrors) of every disk.
- Data is lost only if all disks fail in a timespan too short to copy data to new disks.
- Extra advantage: Allows several I/Os to be carried out in parallel.
- Disadvantage: Need many disks.

Erasure correcting codes
- If a given piece of data is lost, we want to be able to recover it.
- Data encoded as an erasure-correcting code have this property.
- Simple example: To encode bits b_1,b_2,..,b_i store them together with the extra bit (b_1+b_2+..+b_i) mod 2.
- Question: How do we recover b_i if lost?

RAID level 4
- Data resides on n identical disks.
- The last disk contains the sum (mod 2) of bits on the previous n-1 disks. (This is also known as a checksum.)
- Any disk can be recovered from the other disks.
- Advantage: Only one redundant disk.
- Drawback: Last disk is bottleneck.

RAID level 5 and 6
- Ideas:
  - Distribute checksums among disks to avoid write bottleneck.
  - Make resistant to multiple simultaneous crashes.
  - Allow detection and correction of erroneous data from one disk (which is rare, but may happen).
- Example: 5 data and 2 redundant disks.

Conclusion
- Highly stable disk systems are possible, though either a rather high number of disks or high redundancy is needed.
- For protection against fire, meteorites, etc., disks need to be geographically separated.