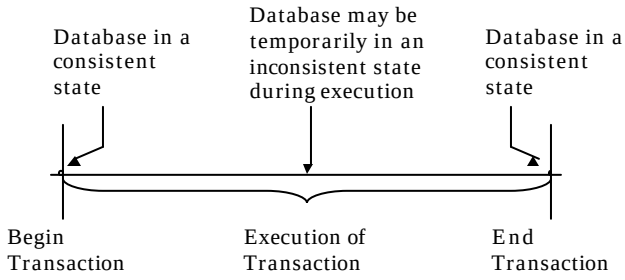
# Transaction

- A transaction is a collection of actions that make consistent transformations of system states while preserving system consistency.
  - concurrency transparency
  - failure transparency






# Transaction Example – A Simple SQL Query

```
…
main() {
  …
  EXEC SQL UPDATE Project
     SET Budget = Budget * 1.1
     WHERE Pname = `CAD/CAM';
  EXEC SQL COMMIT RELEASE;
  return(0);
  …}
```

# Example Database

Consider an airline reservation example with the relations:

FLIGHT(FNO, DATE, SRC, DEST, STSOLD, CAP)
CUST(CNAME, ADDR, BAL)
FC(FNO, DATE, CNAME, SPECIAL)



# Example Reservation Transaction

```
…
main {
…
  EXEC SQL BEGIN DECLARE SECTION;
     char flight_no[6], customer_name[20];
     char day;
  EXEC SQL END DECLARE SECTION;
  scanf(flight_no, day, customer_name);
  EXEC SQL  UPDATE FLIGHT
     SET    STSOLD = STSOLD + 1
     WHERE  FNO = :flight_no AND DATE = :day;
  EXEC SQL  INSERT
     INTO   FC(FNO, DATE, CNAME, SPECIAL);
     VALUES(:flight_no,:day,:customer_name, null);
  printf("Reservation completed");
  EXEC SQL COMMIT RELEASE;
  return(0);}
```

# Termination of Transactions

```
…
main {
…
  EXEC SQL BEGIN DECLARE SECTION;
     char flight_no[6], customer_name[20];
     char day; int temp1, temp2;
  EXEC SQL END DECLARE SECTION;
  scanf(flight_no, day, customer_name);
  EXEC SQL    SELECT STSOLD,CAP INTO :temp1,:temp2
      FROM    FLIGHT
      WHERE   FNO = :flight_no AND DATE = :day;
  if temp1 = temp2 then {
      printf("no free seats");
      EXEC SQL ROLLBACK RELEASE;
      return(-1);}
  else {
      EXEC SQL UPDATE FLIGHT
        SET   STSOLD = STSOLD + 1
        WHERE FNO = :flight_no AND DATE = :day;
      EXEC SQL INSERT
        INTO  FC(FNO, DATE, CNAME, SPECIAL);
        VALUES (:flight_no, :day, :customer_name, null);
      EXEC SQL COMMIT RELEASE;
      printf("Reservation completed");
      return(0);}
}
```



# Characterization

- Read set (RS)
  - The set of data items that are read by a transaction
- Write set (WS)
  - The set of data items whose values are changed by this transaction
- Base set (BS)
  - RS $\cup$ WS

# Formalization

Let

- $o_{ij}(x)$ be some operation $o_j$ of transaction $T_i$ operating on data item $x$, where $o_j \in$ {read,write} and $o_j$ is atomic
- $OS_i = \cup_j o_{ij}$
- $N_i \in$ {abort,commit}

Transaction $T_i$ is a partial order $T_i = \{\Sigma_i, <_i\}$ where

❶ $\Sigma_i = OS_i \cup \{N_i\}$

❷ For any two operations $o_{ij}, o_{ik} \in OS_i$, if $o_{ij} = R(x)$ and $o_{ik}=W(x)$ for any data item $x$, then either $o_{ij}<_i o_{ik}$ or $o_{ik}<_i o_{ij}$

❸ $\forall o_{ij} \in OS_i, o_{ij} <_i N_i$



# Example

Consider a transaction $T$:

Read($x$)
Read($y$)
$x \leftarrow x + y$
Write($x$)
Commit

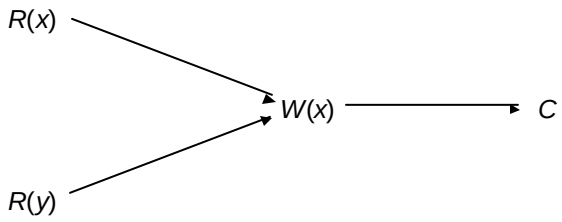
Then

$\Sigma = \{R(x), R(y), W(x), C\}$
$< = \{(R(x), W(x)), (R(y), W(x)), (W(x), C), (R(x), C), (R(y), C)\}$

# DAG Representation

Assume

$< = \{(R(x),W(x)), (R(y),W(x)), (R(x), C), (R(y), C), (W(x), C)\}$






# Properties of Transactions

## ATOMICITY

- all or nothing

## CONSISTENCY

- no violation of integrity constraints

## ISOLATION

- concurrent changes invisible ⇒ serializable

## DURABILITY

- committed updates persist

# Atomicity

- Either all or none of the transaction's operations are performed.
- Atomicity requires that if a transaction is interrupted by a failure, its partial results must be undone.
- The activity of preserving the transaction's atomicity in presence of transaction aborts due to input errors, system overloads, or deadlocks is called transaction recovery.
- The activity of ensuring atomicity in the presence of system crashes is called crash recovery.



# Consistency

- Internal consistency
  - A transaction which executes *alone* against a *consistent* database leaves it in a consistent state.
  - Transactions do not violate database integrity constraints.
- Transactions are correct programs

# Isolation

- Serializability
  - If several transactions are executed concurrently, the results must be the same as if they were executed serially in some order.
- Incomplete results
  - An incomplete transaction cannot reveal its results to other transactions before its commitment.
  - Necessary to avoid cascading aborts.



# Isolation Example

- Consider the following two transactions:

| $T_1$: | | $T_2$: | |
|---|---|---|---|
| | Read($x$) | | Read($x$) |
| | $x \leftarrow x+1$ | | $x \leftarrow x+1$ |
| | Write($x$) | | Write($x$) |
| | Commit | | Commit |

- Possible execution sequences:

| | | | |
|---|---|---|---|
| $T_1$: | Read($x$) | $T_1$: | Read($x$) |
| $T_1$: | $x \leftarrow x+1$ | $T_1$: | $x \leftarrow x+1$ |
| $T_1$: | Write($x$) | $T_2$: | Read($x$) |
| $T_1$: | Commit | $T_1$: | Write($x$) |
| $T_2$: | Read($x$) | $T_2$: | $x \leftarrow x+1$ |
| $T_2$: | $x \leftarrow x+1$ | $T_2$: | Write($x$) |
| $T_2$: | Write($x$) | $T_1$: | Commit |
| $T_2$: | Commit | $T_2$: | Commit |

# Consistency Degrees (due to Jim Gray)

- Degree 0
  - Transaction *T* does not overwrite dirty data of other transactions
  - Dirty data refers to data values that have been updated by a transaction prior to its commitment
- Degree 1
  - *T* does not overwrite dirty data of other transactions
  - *T* does not commit any writes before EOT



# Consistency Degrees (cont'd) (due to Jim Gray)

- Degree 2
  - *T* does not overwrite dirty data of other transactions
  - *T* does not commit any writes before EOT
  - *T* does not read dirty data from other transactions
- Degree 3
  - *T* does not overwrite dirty data of other transactions
  - *T* does not commit any writes before EOT
  - *T* does not read dirty data from other transactions
  - Other transactions do not dirty any data read by *T* before *T* completes.

# SQL-92 Isolation Levels

Phenomena:

- Dirty read
  - $T_1$ modifies $x$ which is then read by $T_2$ before $T_1$ terminates; $T_1$ aborts $\Rightarrow$ $T_2$ has read value which never exists in the database.
- Non-repeatable (fuzzy) read
  - $T_1$ reads $x$; $T_2$ then modifies or deletes x and commits. $T_1$ tries to read $x$ again but reads a different value or can't find it.
- Phantom
  - $T_1$ searches the database according to a predicate while $T_2$ inserts new tuples that satisfy the predicate.



# SQL-92 Isolation Levels (cont'd)

- Read Uncommitted
  - For transactions operating at this level, all three phenomena are possible.
- Read Committed
  - Fuzzy reads and phantoms are possible, but dirty reads are not.
- Repeatable Read
  - Only phantoms possible.
- Anomaly Serializable
  - None of the phenomena are possible.

# Durability

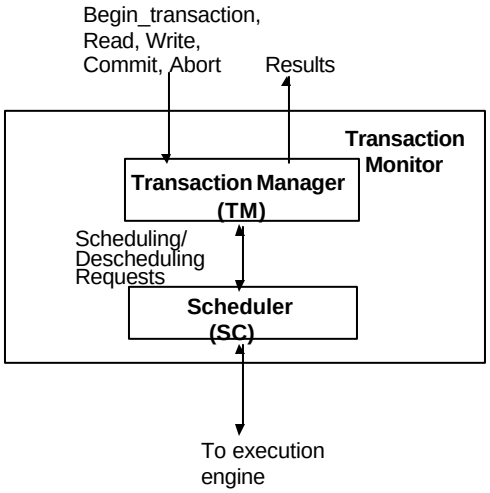
- Once a transaction commits, the system must guarantee that the results of its operations will never be lost, in spite of subsequent failures.
- Database recovery



# Transactions Provide…

- *Atomic* and *reliable* execution in the presence of failures
- *Correct* execution in the presence of multiple user accesses
- Correct management of *replicas* (if they support it)

# Architecture






# Transaction Execution