System R
cs262a, Lecture 2

Rishabh Iyer

(Adapted from slides by Hellerstein, Stoica, Ghodsi)

Databases

Store two types of information. What are they?

- » Contents of records
- » How records are connected together.

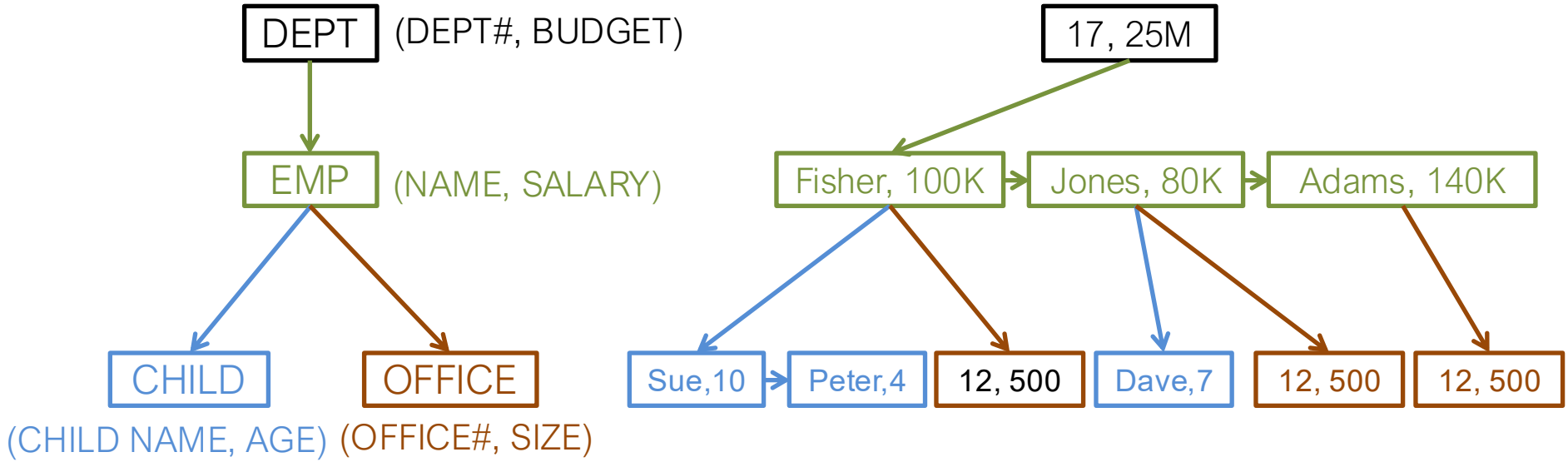
How do you search a database?

- » You specify detailed algorithms that traverse the connections to get the answer.

Examples: search/insert/delete in linked lists, trees, etc

Before relational DBs: hierarchical and network

Hierarchical Model*



1966: IMS (IBM Management System)

» Designed for Apollo program for managing inventory for Saturn V and space vehicle

*examples from "Network hierarchies and relations in database management systems" by M. Stonebraker and G. Held

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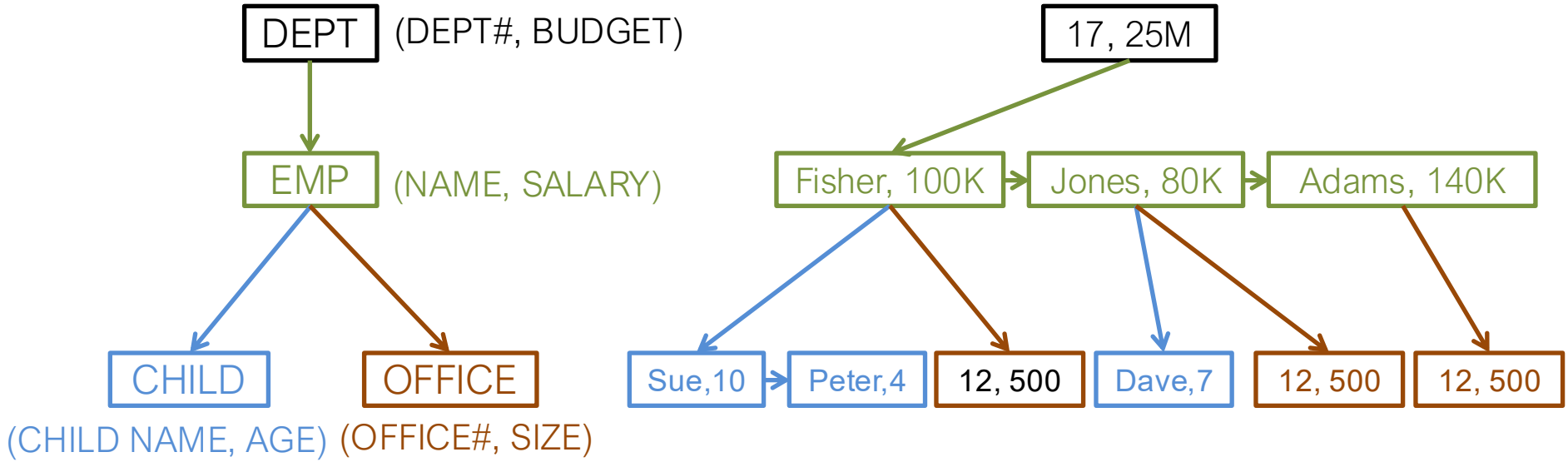


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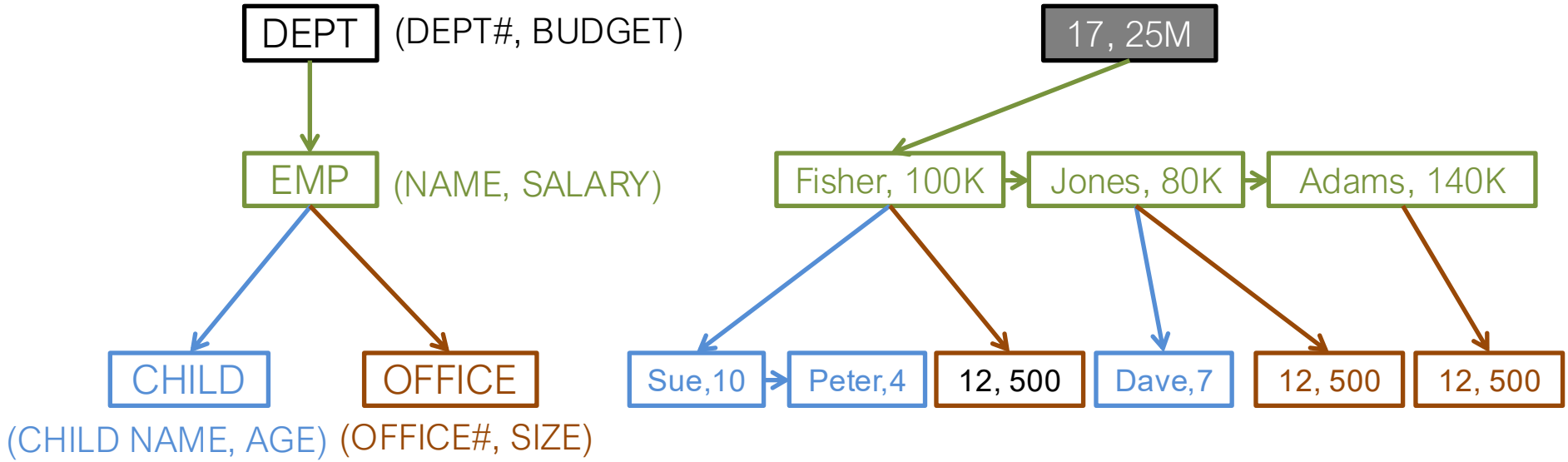


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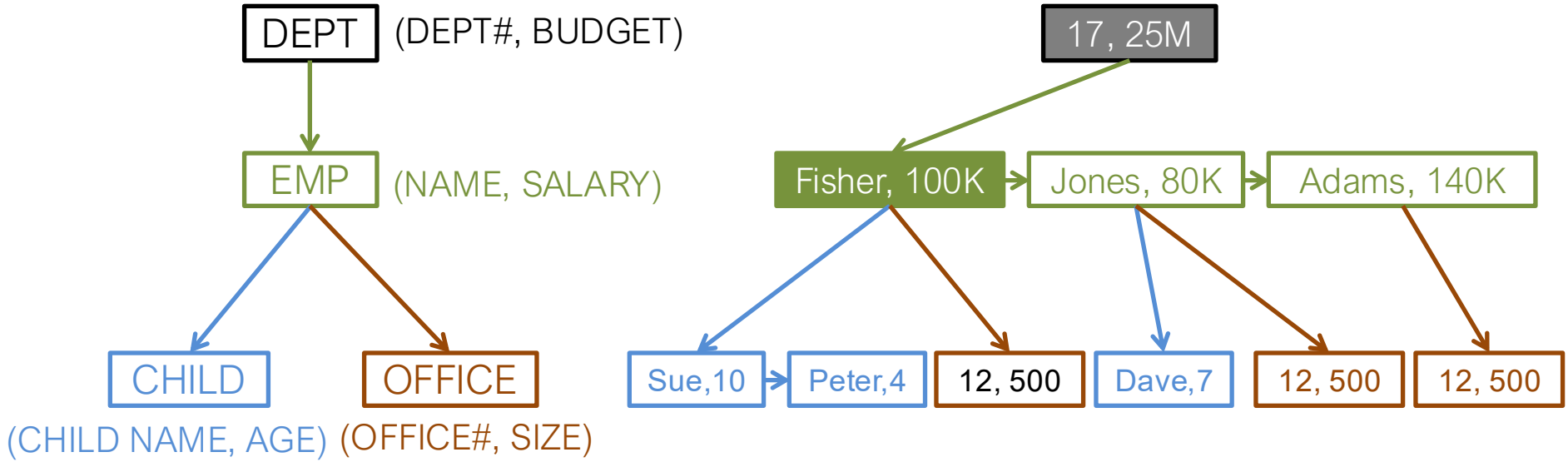


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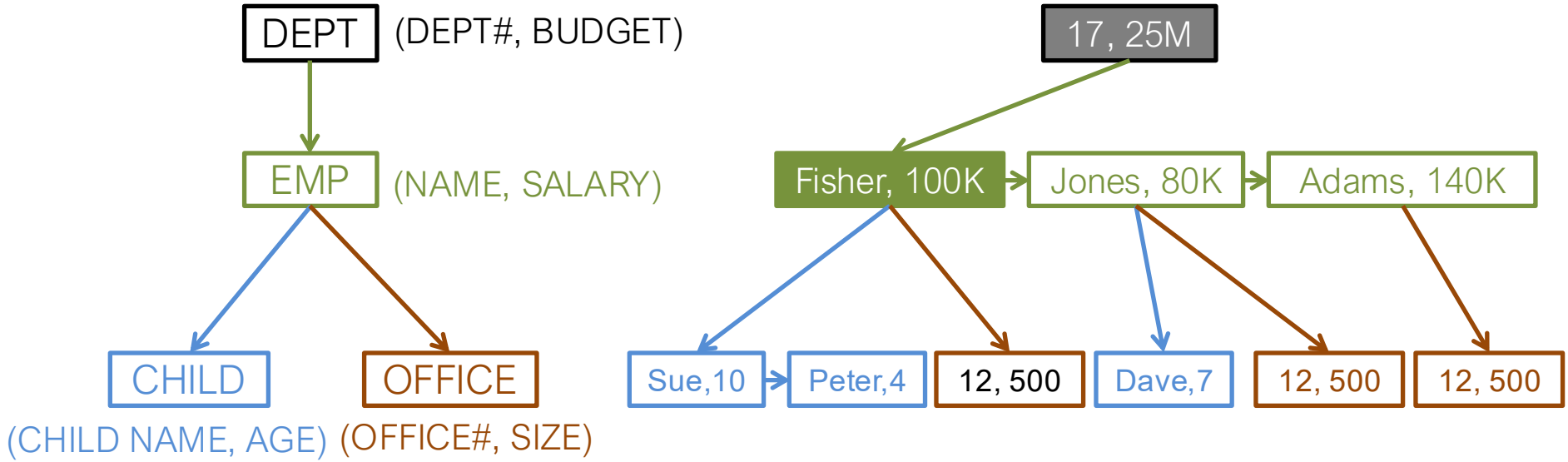


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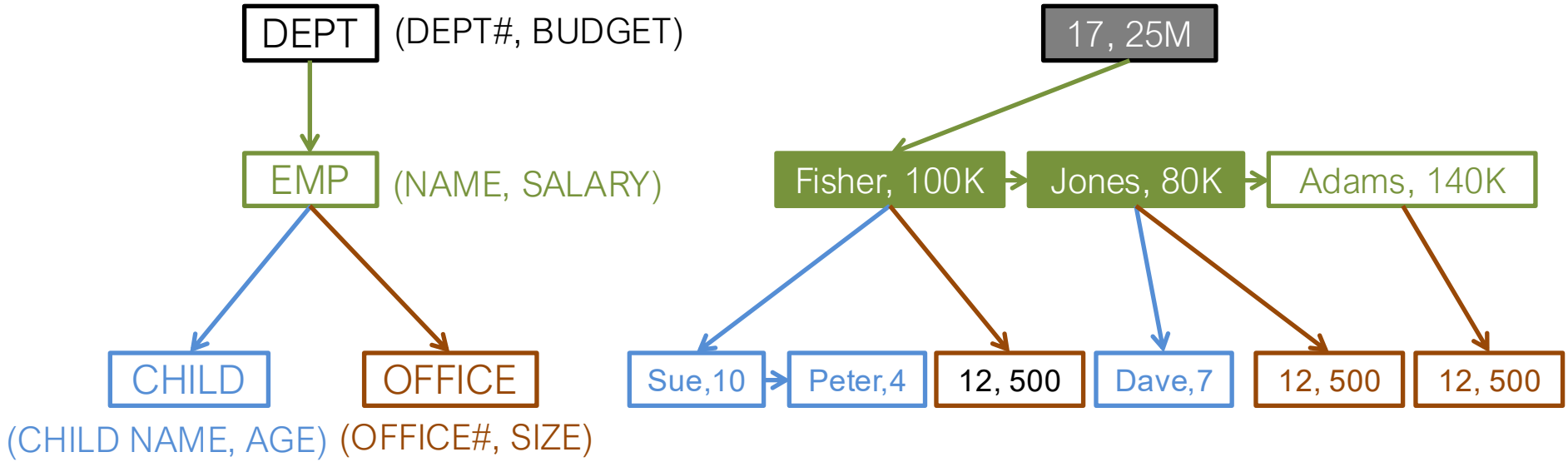


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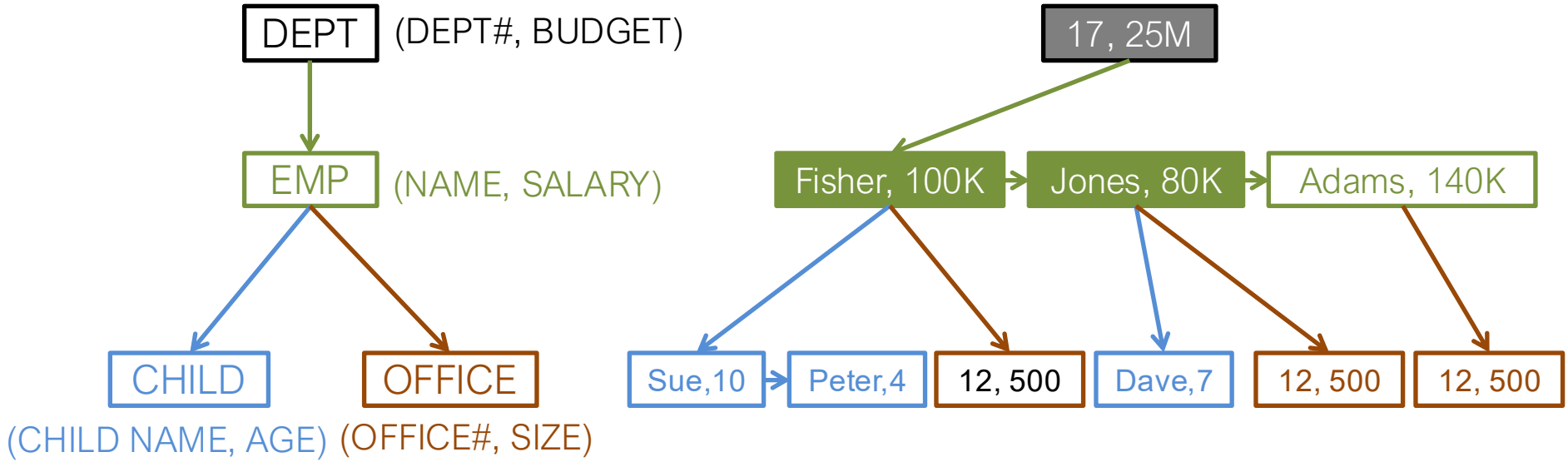


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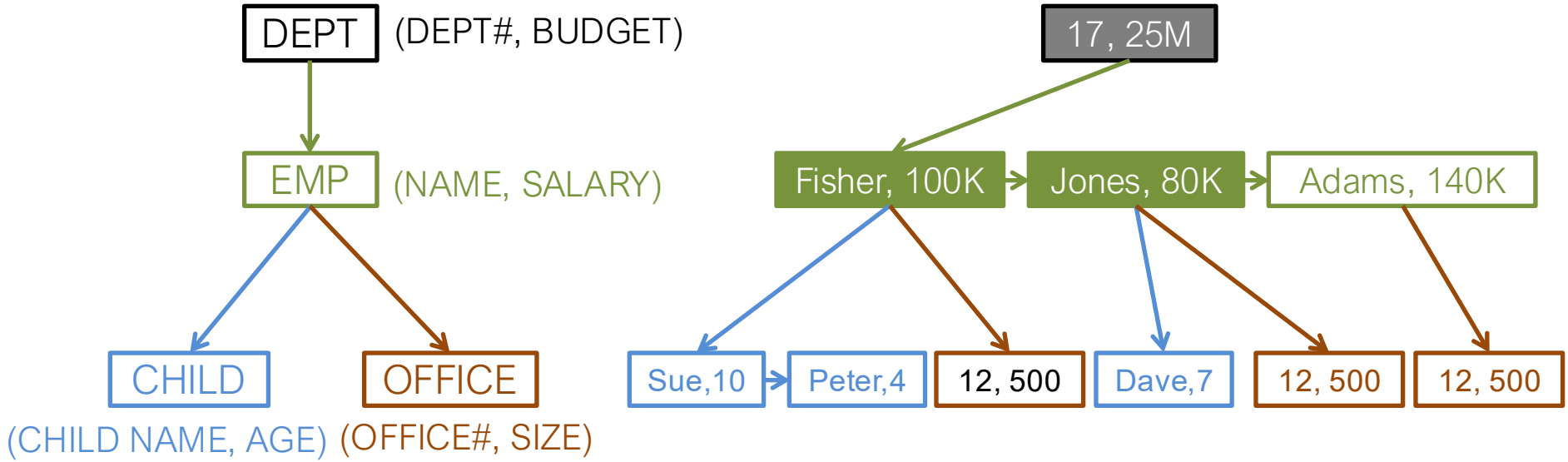


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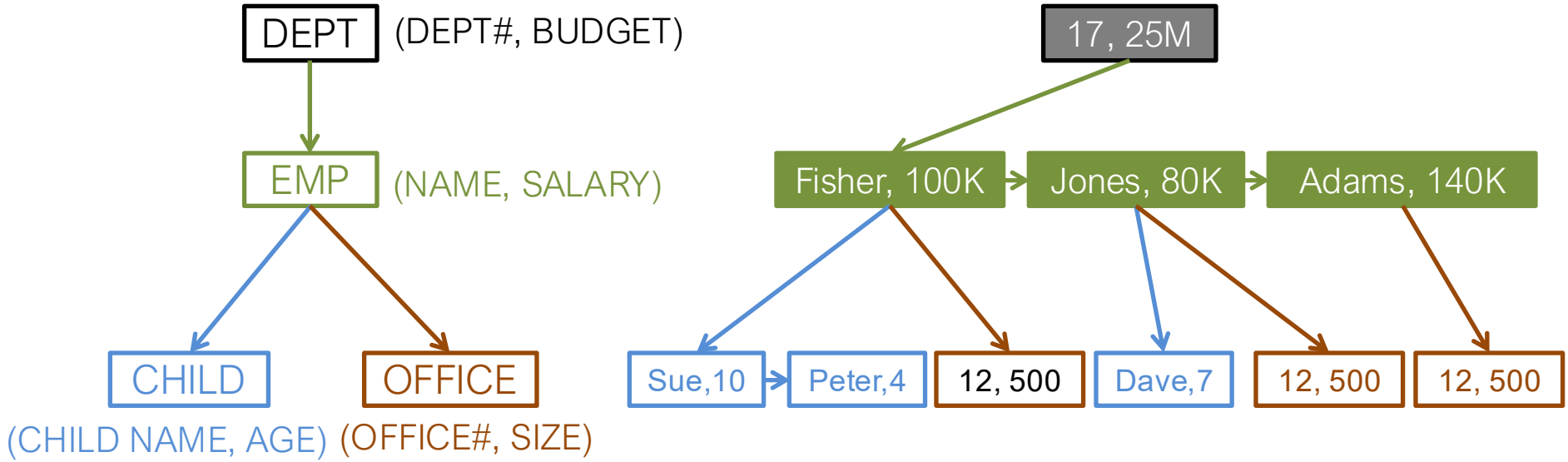


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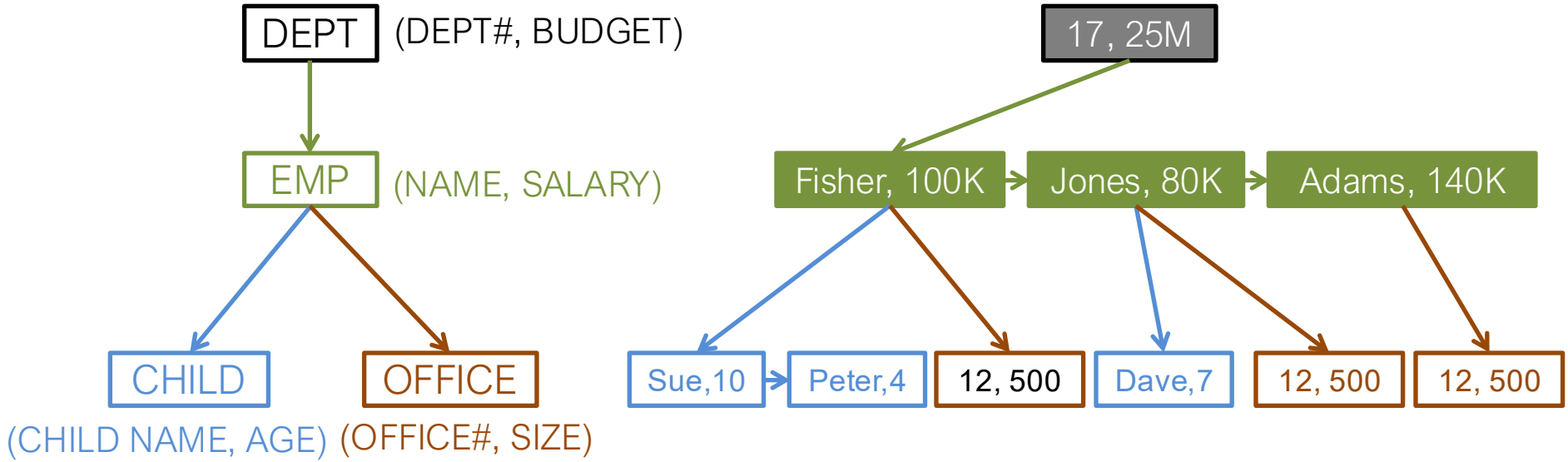


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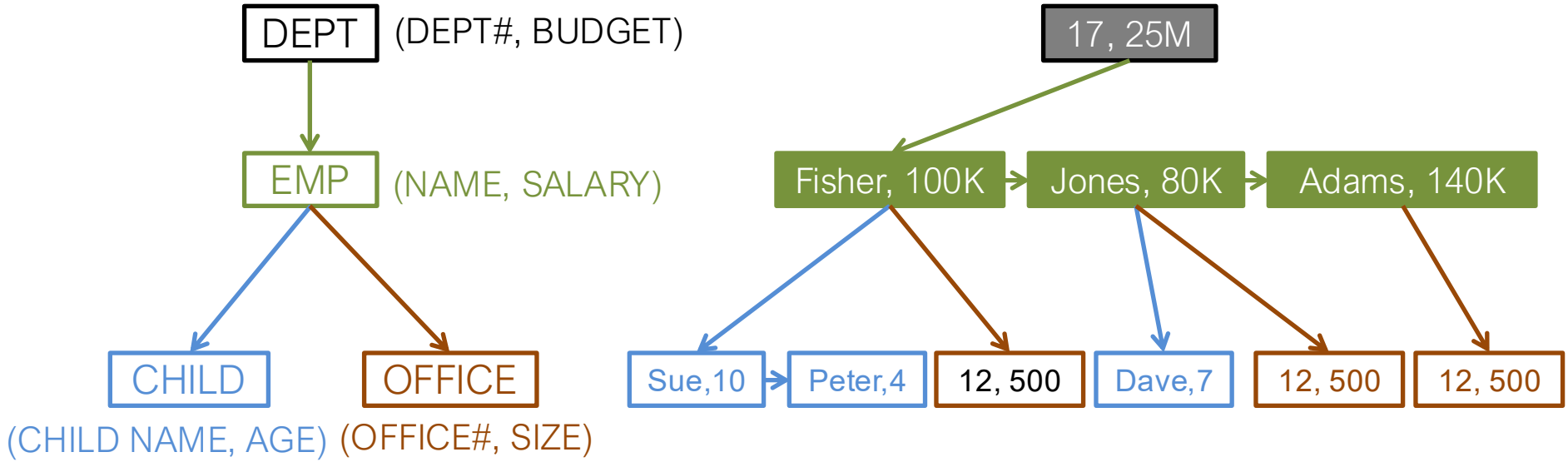


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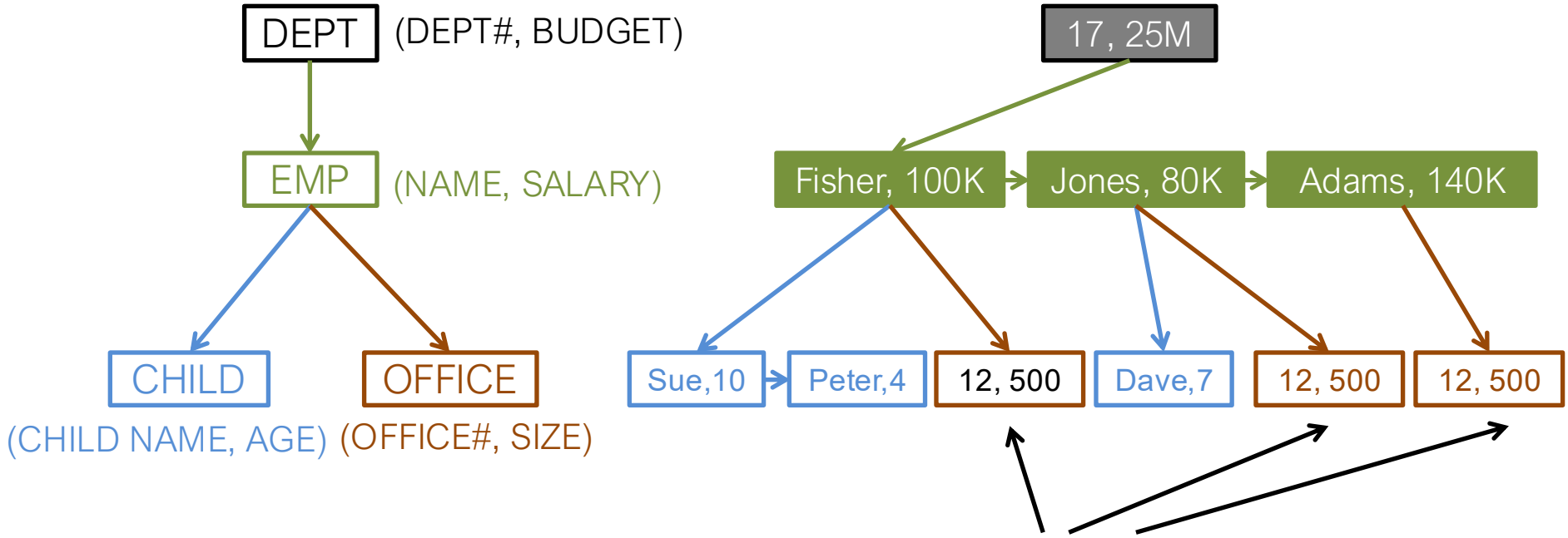
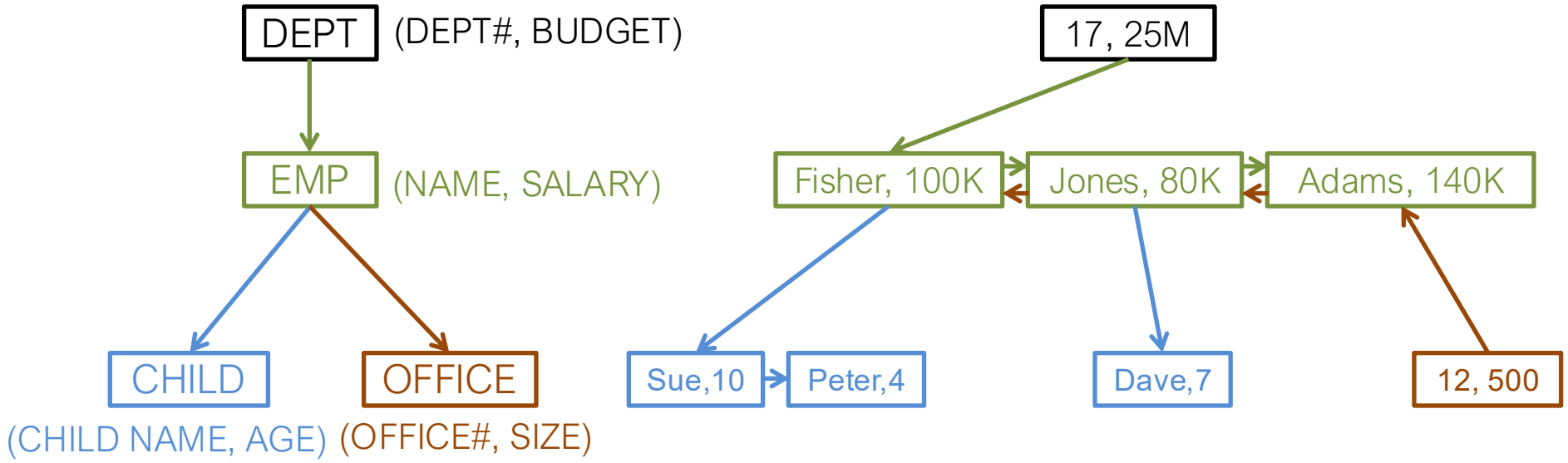
Output: Fisher Jones Adams

Hierarchical Model: Challenges



1) Duplicate records
2) Requirements to have a parent; deletion anomalies

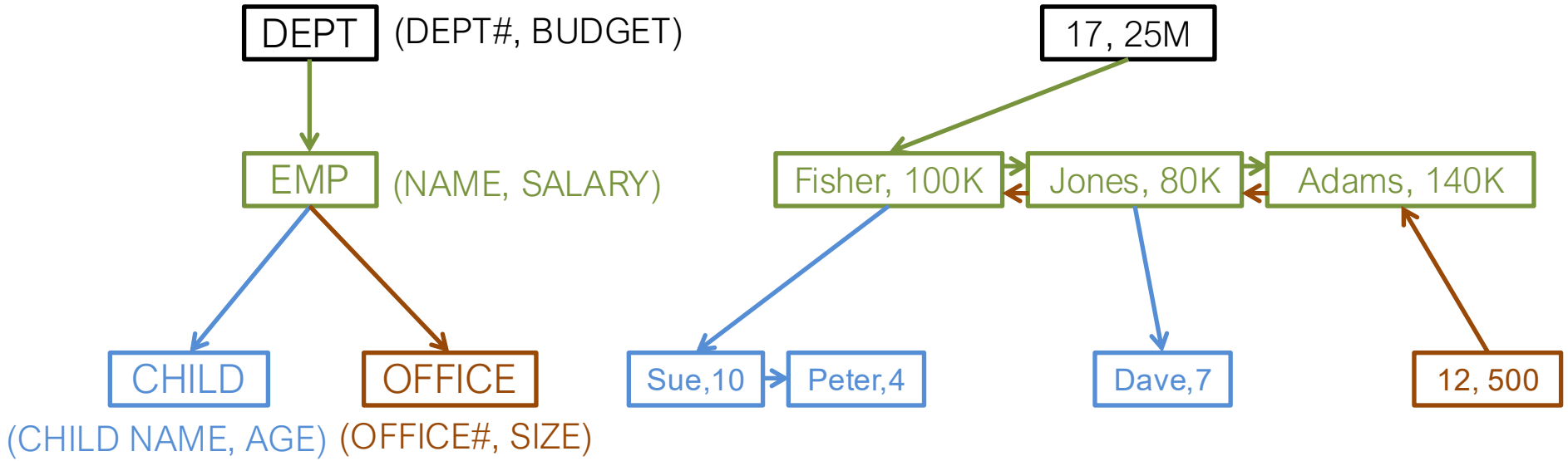
Network Model



CODASYL (Conference/Committee on Data Systems Languages)

» 1969: CODASYL data model
Designed by **Charles Bachman**,
Turing Award, 1973

Network Model*

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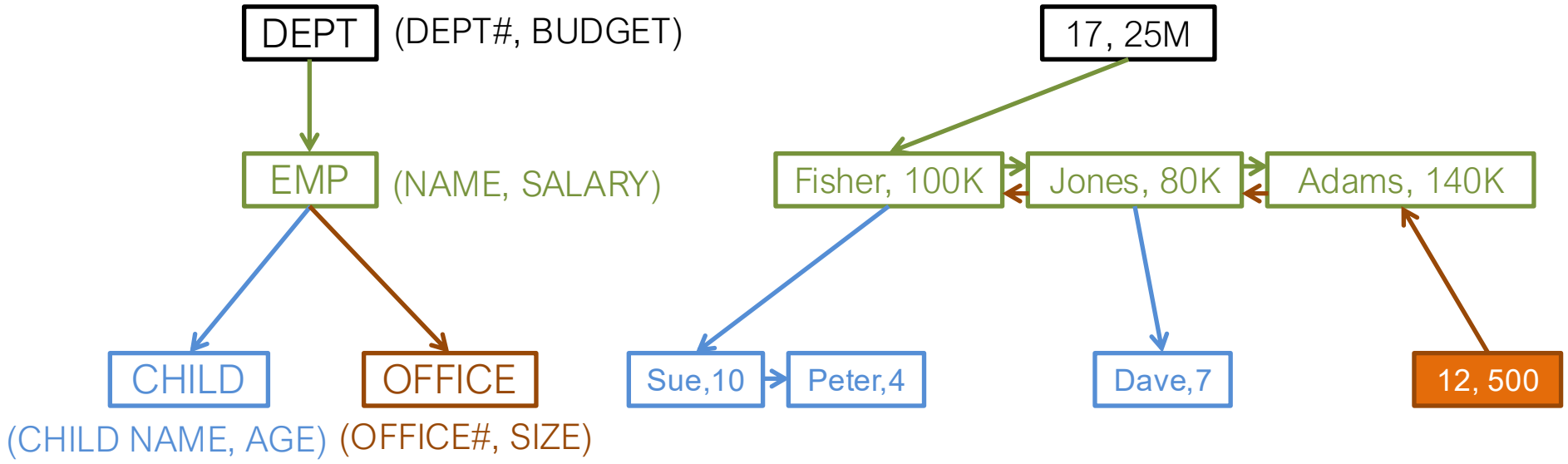


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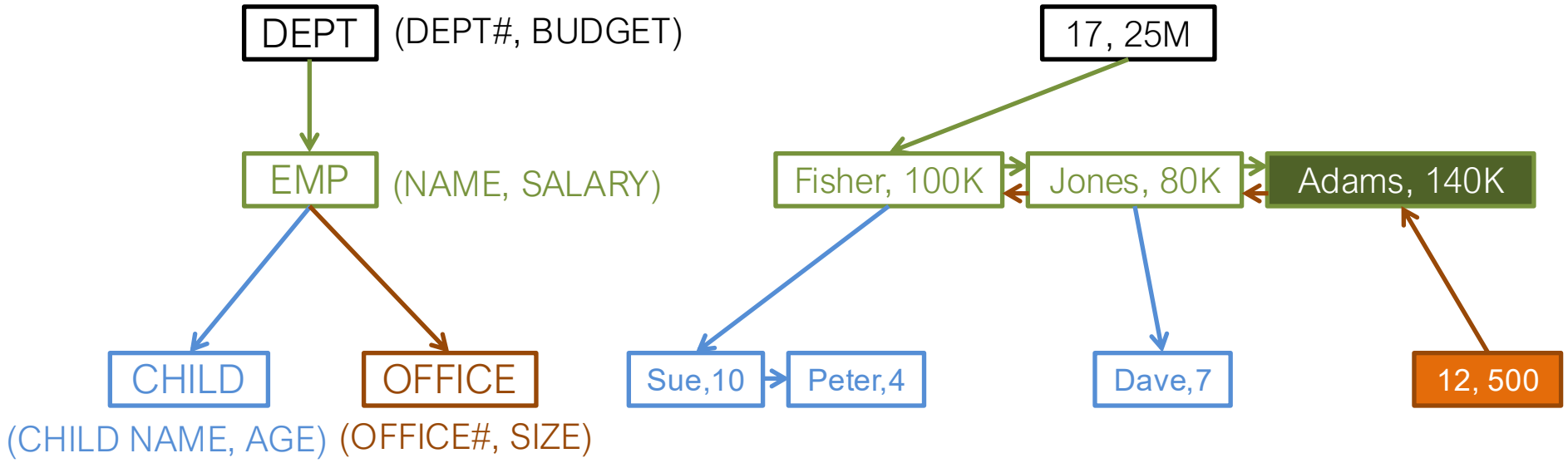


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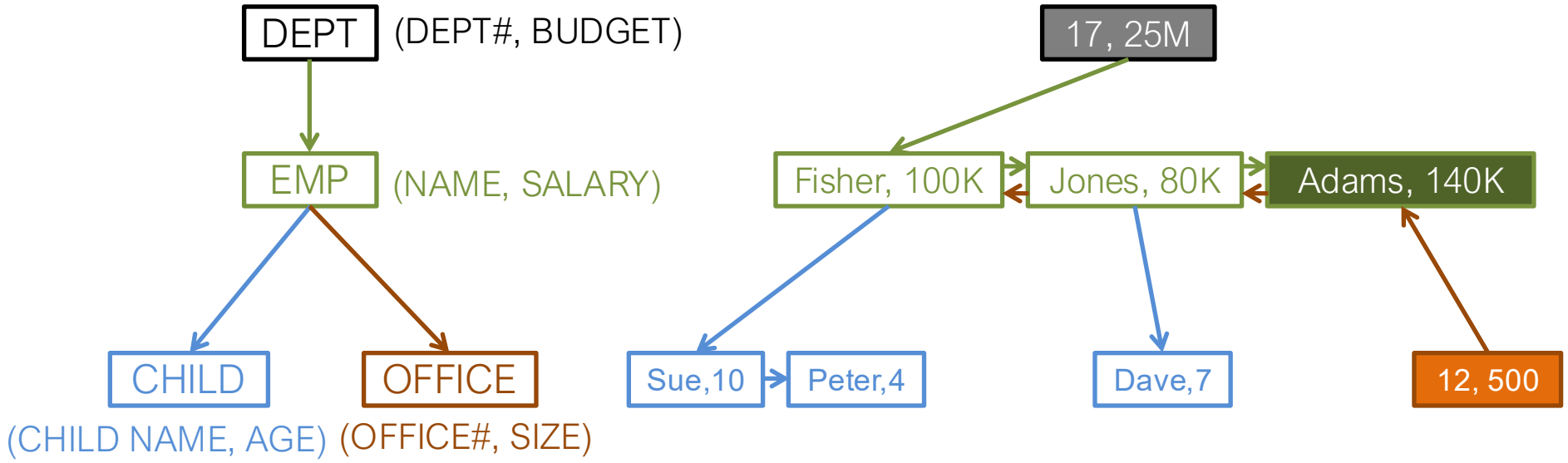


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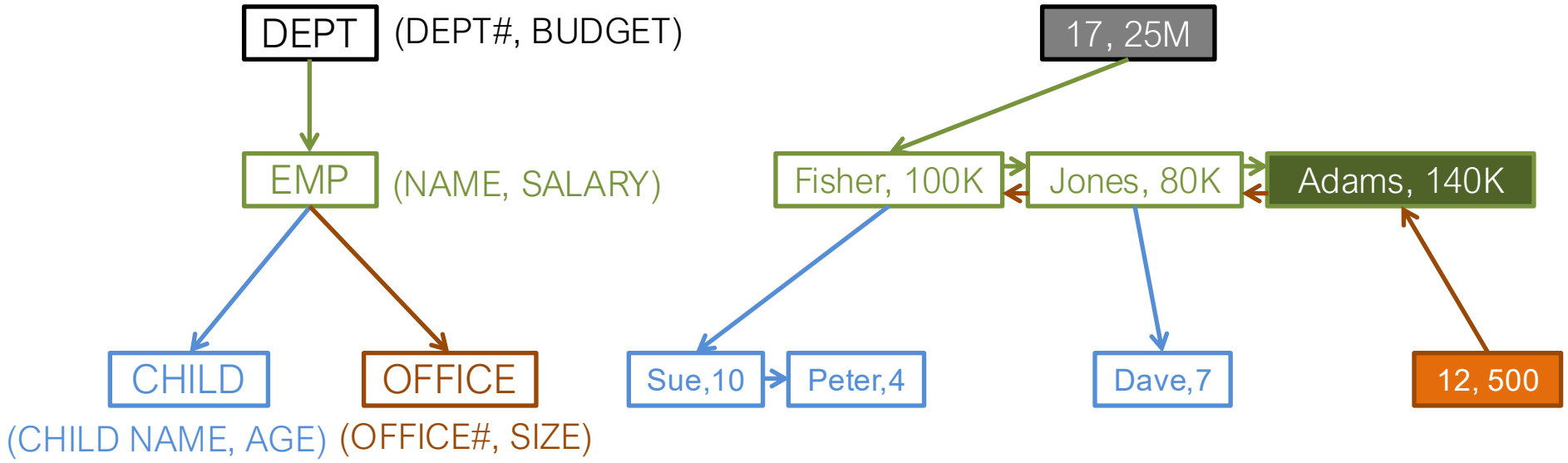


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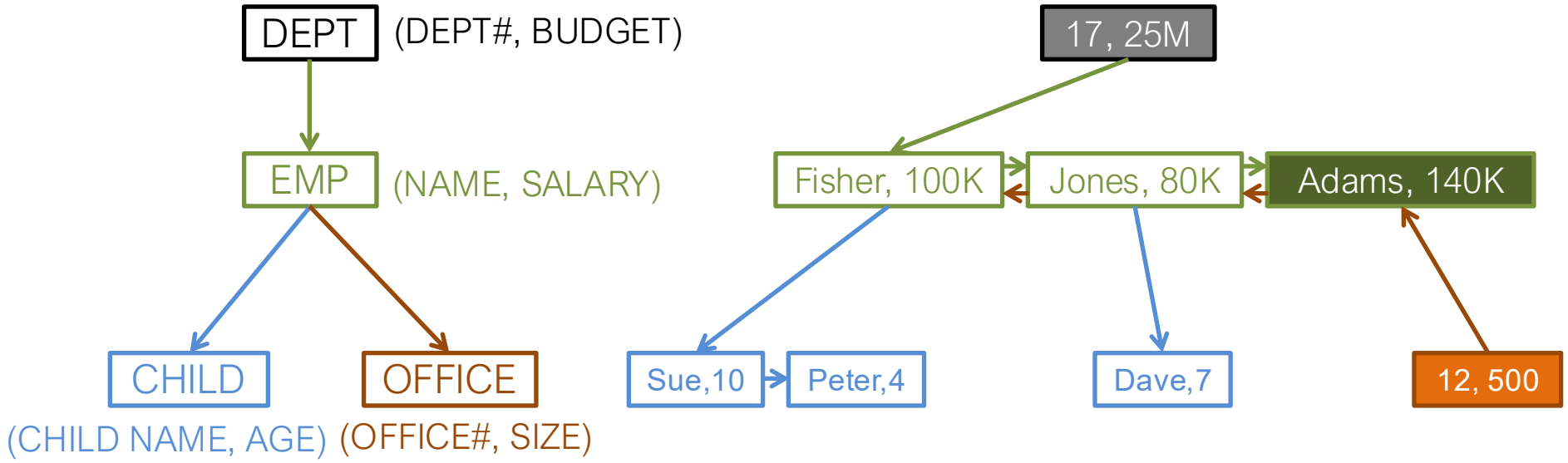


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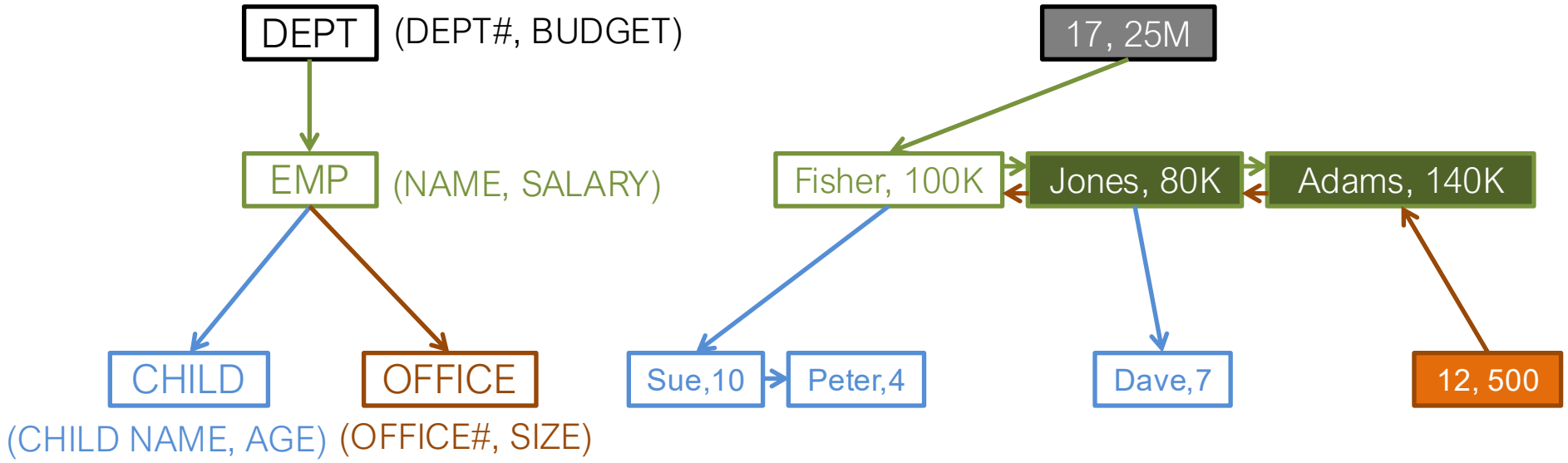


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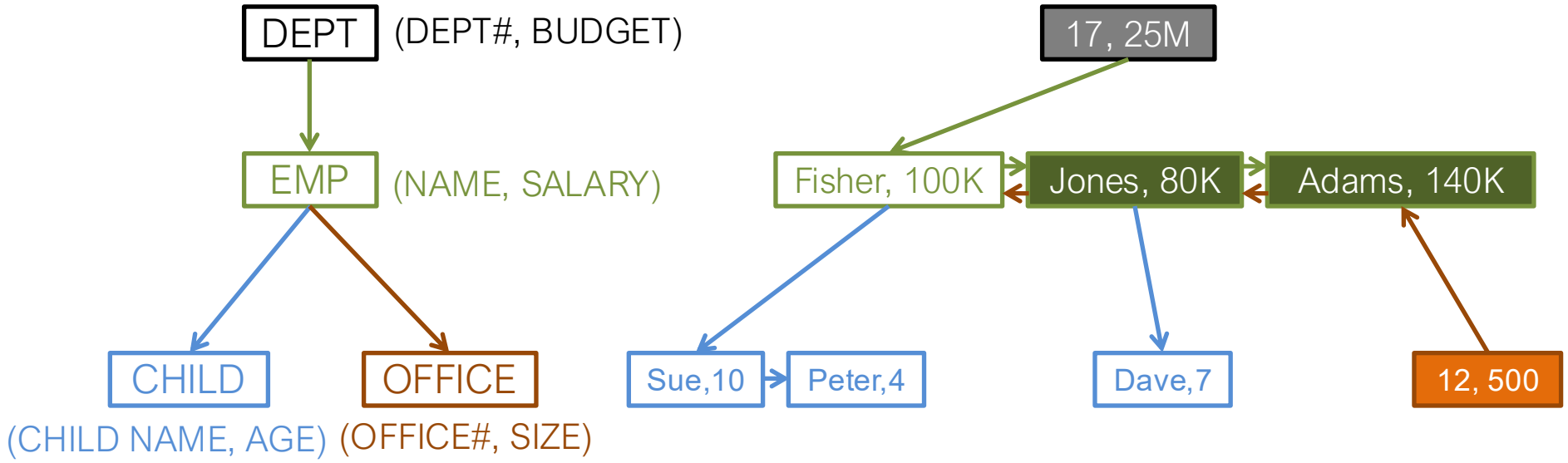


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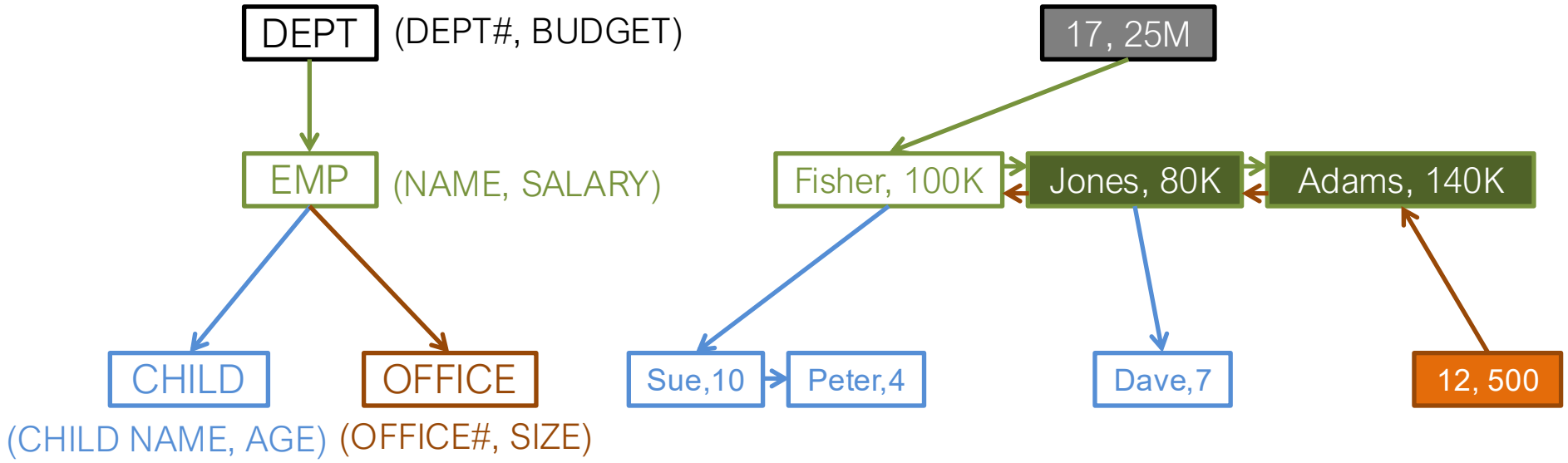


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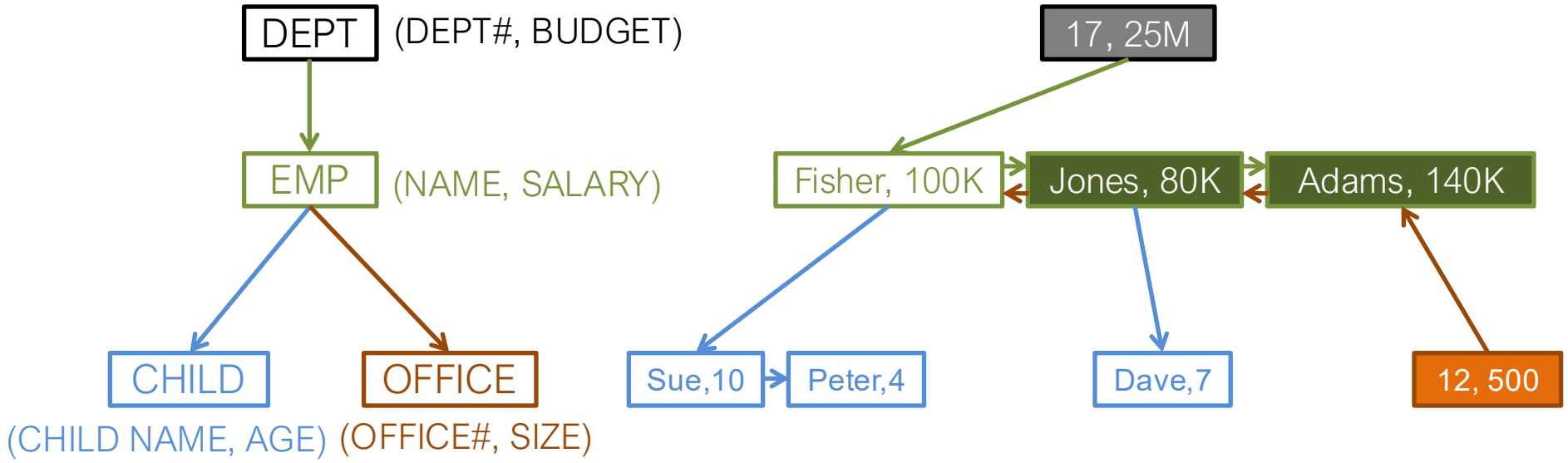


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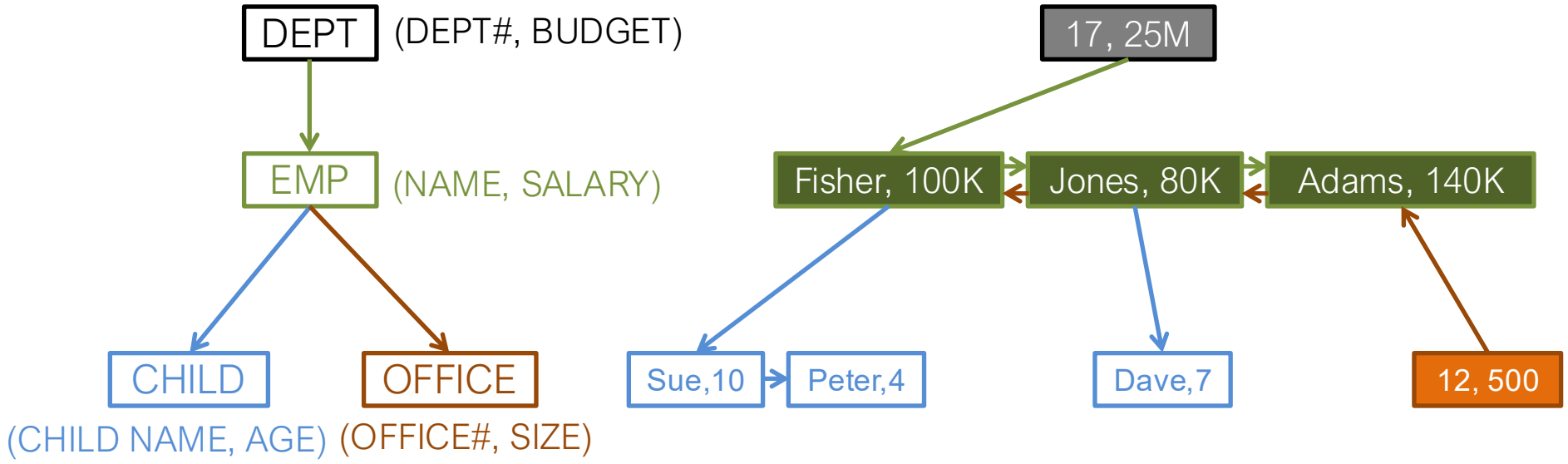


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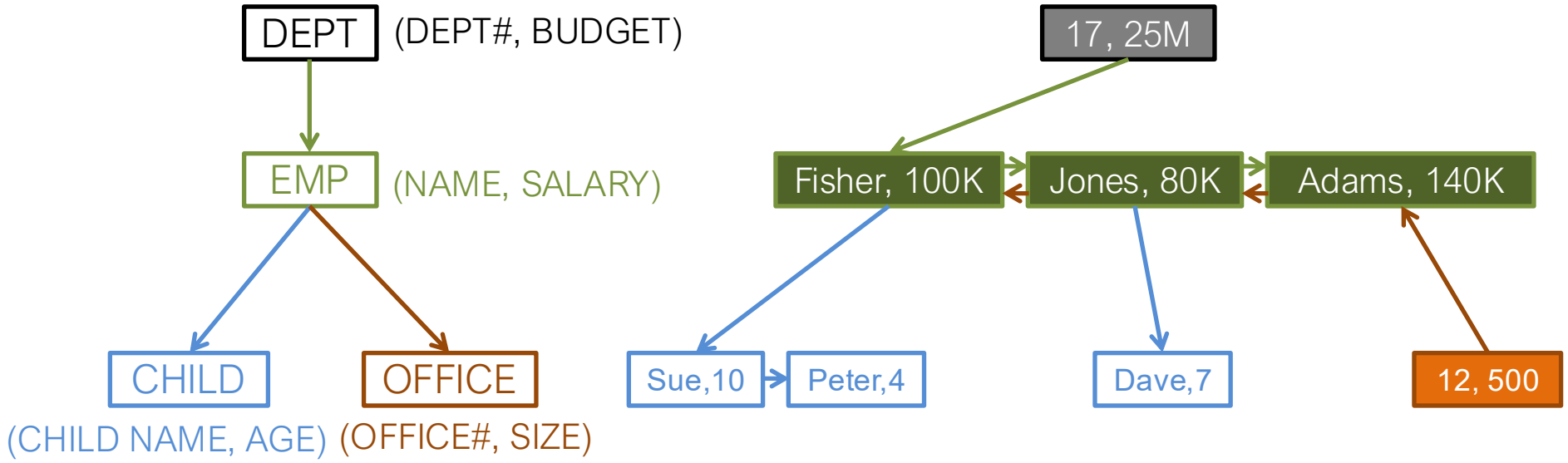


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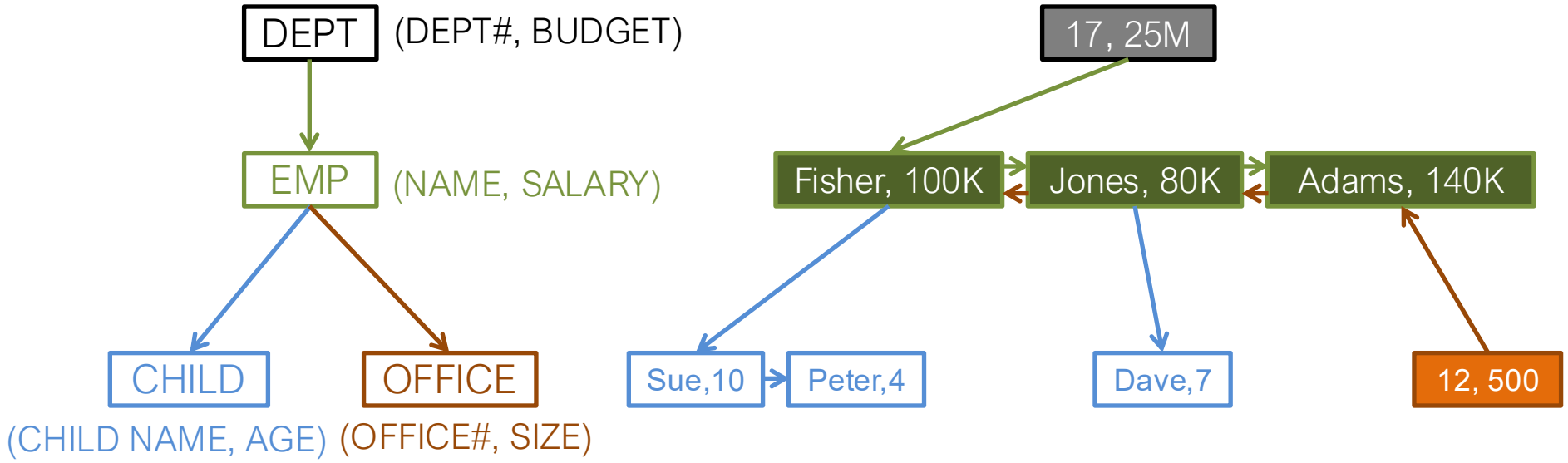


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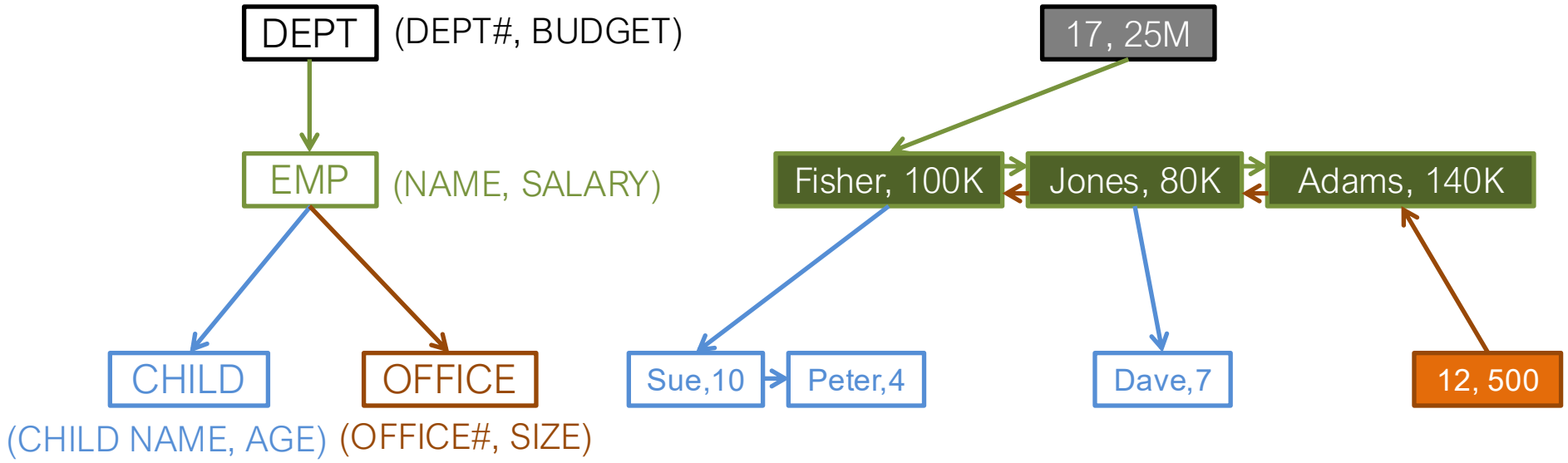


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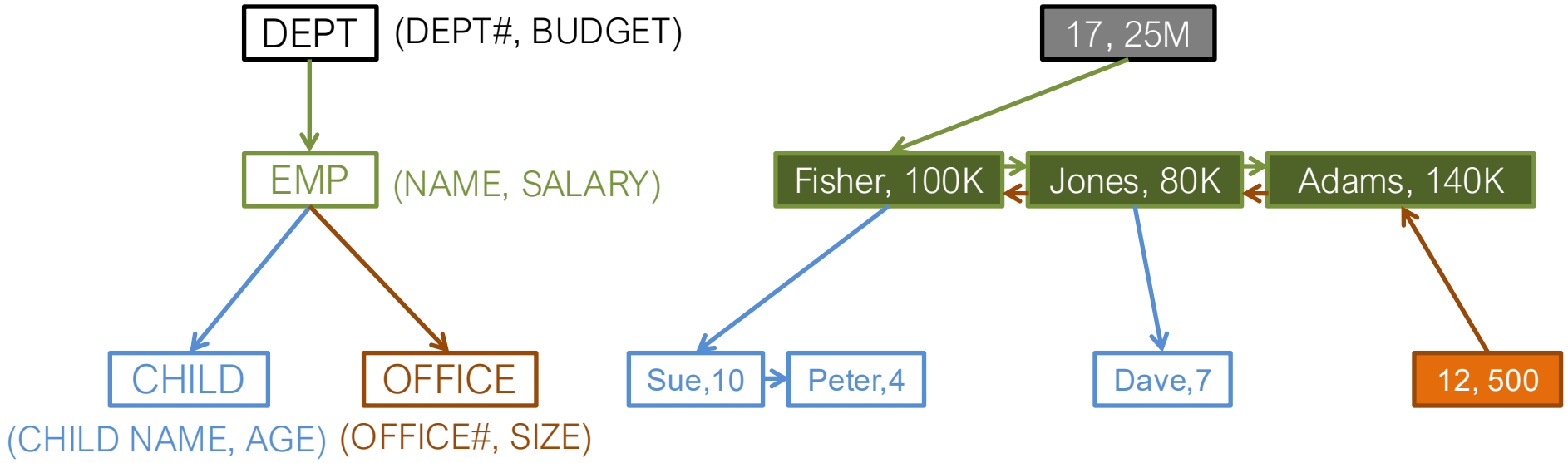


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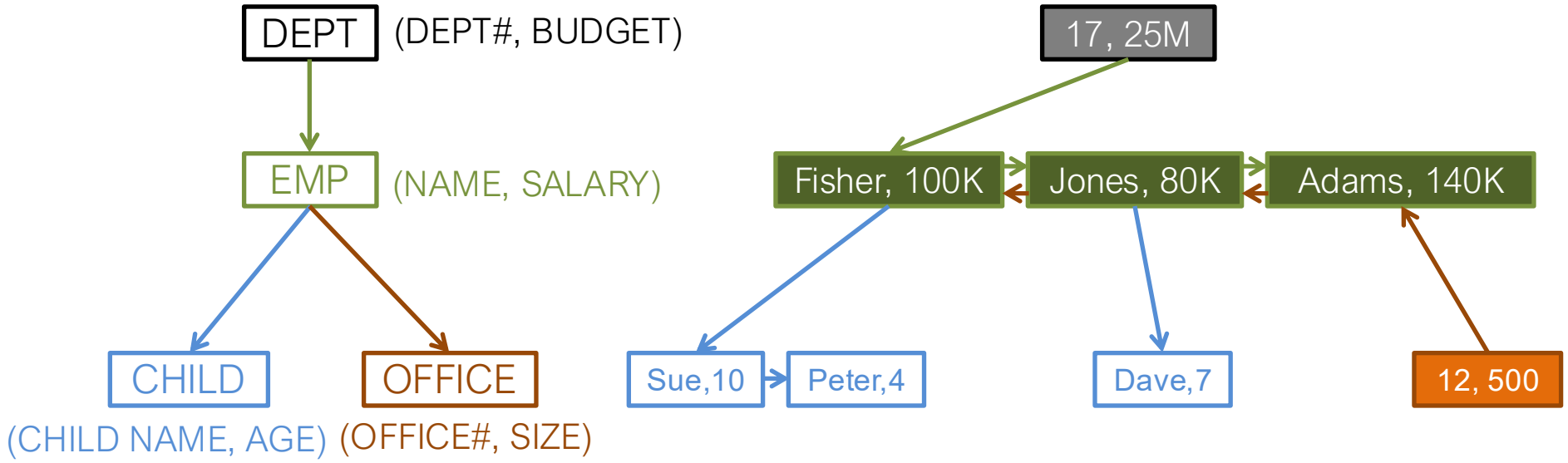


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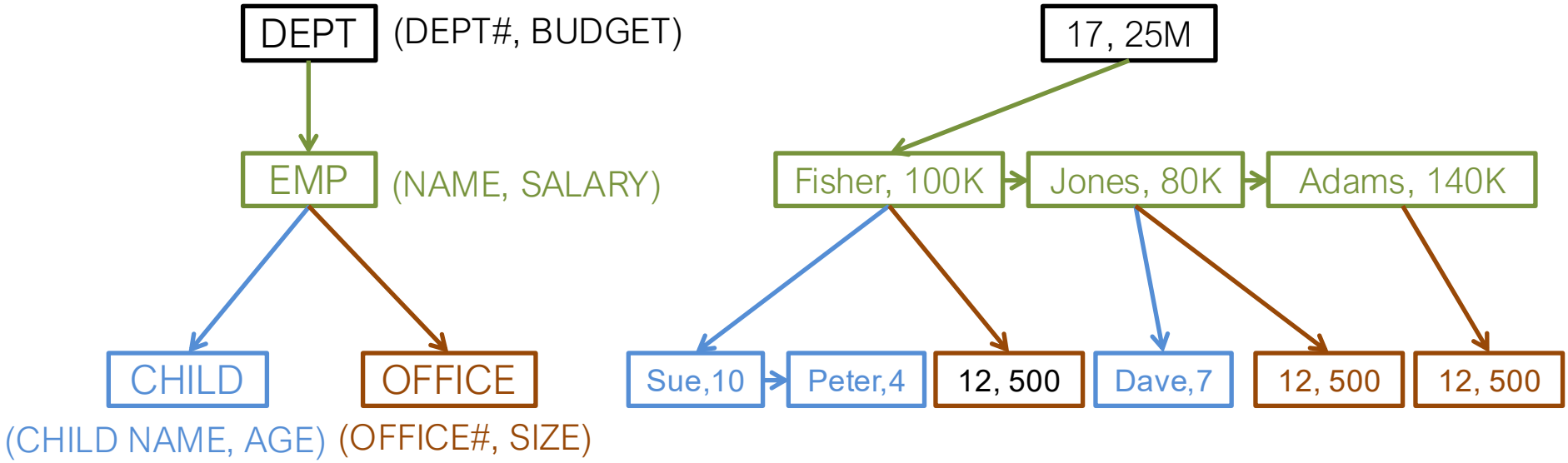
Data Dependence

Record-at-a-time Data Manipulation Language (DML)

Reflect physical data structures

If you want to change the data organization you need to change query!

Example: Changing Data Representation

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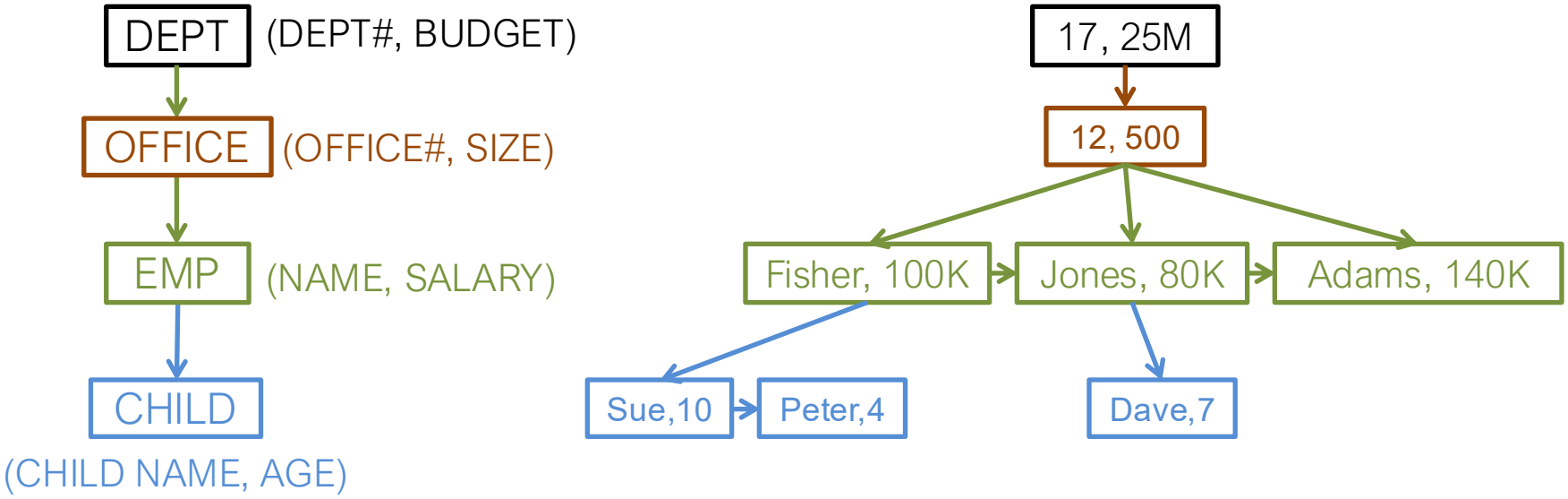


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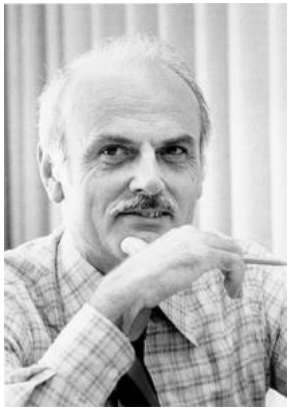
Relational Database



1970 Edgar Codd's paper; probably the most influential paper in DB research

- » Set-at-a-time DML
- » **Data independence**: allows for schema and physical storage structures to change
  - *"as clear a paradigm shift as we can hope to find in computer science"* – Christos Papadimitriou
- » 1981 Turing Award

Relational Database: Two key ideas

1. Store values only, no connections
   - » Everything is a table
2. Declarative query language, leaves implementation and algorithm unspecified

Relational Model

Links represented as tables

DEPT	#	BUDGET
	17	25M

OFFICE	#	SIZE
	12	500

CHILD	C. NAME	C. NAME
	Sue	10
	Peter	4
	Dave	7

EMP	NAME	SALARY
	Fischer	100K
	Jones	80K
	Adams	140K

OFFSPRINGS	NAME	C. NAME
	Fischer	Sue
	Fischer	Peter
	Jones	Dave

WORKS	DEPT#	NAME
	17	Fisher
	17	Jones
	17	Adams

OCCUPIED	NAME	OFFICE #
	Fischer	12
	Jones	12
	Adams	12

```
# find department number of all employees in office 12
FIND ALL DEPT# in WORKS
    WHERE NAME = NAME IN OCCUPIED WHERE OFFICE# = 12
```

Data Independence

Separation into three levels:

- » physical storage
- » logical schema
- » multiple views

Two levels of independence:

- » physical data independence: you change the storage layout without affecting apps
- » logical data independence: isolates apps from changes in logical schema (almost, as it can't update views in general)

Data Independence

Critical for database evolution – allow databases live and evolve for a long time!

Need data independence when environment changes much faster than applications

- Environment: physical storage, machine speed, machine workload

First Relational Databases

Mid 70's: Codd's vision implemented by two projects: ancestors of essentially all today's commercial systems!

- » Ingres (UC Berkeley)
- » System R (IBM)

Lots of crosspollination between both groups

Ingres & System R

Ingres: 1974-77, UC Berkeley: Stonebraker, Wong and many others

- » 2015 Turing Award (Stonebraker)
- » Ancestor of MS SQL Server, Sybase.

System R: IBM San Jose (now Almaden).

- » 15 PhDs, including Jim Gray (1st CS PhD @Cal)
- » 1998 Turing Award (Gray)
- » Ancestor of Oracle, DB2.

Discussion

R System Goals

1. To provide a high-level, non-navigational user interface for maximum user productivity and data independence.
2. To support different types of database use including programmed transactions, ad hoc queries, and report generation.
3. To support a rapidly changing database environment, in which tables, indexes, views, transactions, and other objects could easily be added to and removed from the database without stopping the system.
4. To support a population of many concurrent users, with mechanisms to protect the integrity of the database in a concurrent-update environment.
5. To provide a means of recovering the contents of the database to a consistent state after a failure of hardware or software.
6. To provide a flexible mechanism whereby different views of stored data can be defined and various users can be authorized to query and update these views.
7. To support all of the above functions with a level of performance comparable to existing lower-function database systems.

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1. Easy of use
2. Unifying abstraction
3. Evolvability (of database)
4. Concurrency
5. Fault tolerance
6. Access control (and flexibility)
7. Performance

Development: Phase 0

Expect to throw out the 1st version of the system. Why?

Query Optimization: Phase Zero vs One

Phase Zero focus: optimize complex queries

Phase One focus: optimize simple, most common queries

General systems wisdom: Always optimize the common case!

Locking:
Phase Zero vs One

Phase Zero: “predicate locks” deemed to complicated

Phase One: per object locks, albeit hierarchical and multiple granularity

Will focus on this in class 4. Will be discussing Gray’s seminal paper.

Storage: Phase Zero vs One

Phase Zero: single user, XRM

- Values of each column stored in a separate domain
- Each field contains TID of corresponding domain/value
- Inversions: mapping between values and TIDs

Phase One: multiuser, RSS

- Tuple contains values
- Indexes on one, more, or combination of columns

Cost Based Optimizer: Phase Zero vs One

Phase Zero: per-tuple cost

Phase One: combination of

- # of I/Os
- # of calls (CPU activity)

Questions

- How well does it work?
- Do you expect CPU to still be bottleneck today?
- Caveats?

Others Design Decisions

Interpretation vs. compilation?

Shadow pages vs write ahead logging?

Three levels of transactions (class 4)

Interpretation vs Compilation

System R used compilation, even for ad-hoc queries since code generation was surprisingly cheap.

What is the fundamental tradeoff here? What do modern systems use?

System R Reliability

Component failure as common case

Three failure cases:

1. System failure
2. Media (disk) failure
3. Transaction failure

Discussion: Reliability

Shadow pages vs WAL

- » Key decision: Where does the copy needed for crash-recovery live?
- » Shadow pages: temporary copy of page.
- » WAL: Dedicated log of all database updates

Tradeoffs?

- » How does modern storage HW, particularly SSDs potentially change the tradeoff?

Unix vs. System R

UNIX paper: "The most important job of UNIX is to provide a file system”

- » UNIX and System R are both "information management" systems!

Both also provide programming APIs for apps

Unix vs. System R: Goals

Ease of use:

- Unix: “most important characteristics of the system are its **simplicity**, **elegance**, and **ease** of use.”
- System R: “The system was mostly used in applications for which **ease** of installation, a **high-level user language**, and an ability to rapidly reconfigure the database were important requirements.”

Unix vs. System R: Reuse

Unix

- » Written in the developer language, C
- » Directories as files
- » I/O naming as file naming
- » Same security mechanism for I/O devices & files
- » Shell, just another process

System R?

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System R?

- Relations as tables
- Catalogs as tables
- Views: any SQL query to be used as view definition
- …

Unix vs. System R: Philosophy

Bottom-Up (elegance of system) vs. Top-Down (elegance of semantics)

UNIX main function: *present hardware to computer programmers*

» small *elegant* set of mechanisms, and abstractions for developers (i.e. C programmers)

System R: *manage data for application programmer*

» complete system that insulated programmers (i.e. SQL + scripting) from the system, while guaranteeing clearly defined *semantics* of data and queries.

Unix vs. System R: Philosophy

Bottom-Up (elegance of system) vs. Top-Down (elegance of semantics)

Affects where the complexity goes: to system, or end-programmer?

Which one is better? In what environments?

Summary

Key advantages of relational databases:

- Can change data layout without breaking things
- Don't need to worry about coming up with algo.
- Don't need to be a genius to query.
- More readable queries (no convoluted algo query).
- Database can come up with algo; algo and layout can be dynamic over time
- Apps don't need to be recompiled. Just upgrade database and get speedup.
- Database can adapt to new hardware, apps don't need to worry

Summary

Disadvantages of relational databases:

» Hard to express certain things in declarative form

» Could be slower for small simple imperative queries