

# Topic 6:

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## Relational Calculi

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## Meanings of ‘Calculus’

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- Calculus refers to any method or system of calculation
- ‘Calculus’ is derived from the Latin word for ‘pebble.’
- Modern uses of the word include:
  - Differential Calculus: instantaneous rates of change
  - Integral Calculus: limits of sums of terms
  - Lambda Calculus: functional abstraction & application
  - Predicate Calculus: reasoning about symbolic logic

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## Review of First–Order Predicate Calculus (FOPC) (1 / 2)

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Why? Because FOPC  $\Rightarrow$  Relational Calculus  $\Rightarrow$  SQL

FOPC (a.k.a. First–Order Logic):

- Uses statements of the form “ $P(x)$ ”, where  $P$  is a predicate and  $x$  is a subject
- In FOPC, subjects may be values; they may not be predicates (see: Second-Order Logic)
- FOPC can formalize all of set theory
  - Recall that the Relational Model is based on set theory

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## Review of First–Order Predicate Calculus (FOPC) (2 / 2)

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Supplied Primitives Include:

Variables, Logical Operators, Quantifiers, ...

Constructs of Our Creation Include:

Constants, Predicates, Functions (e.g.  $n^2$ ), ...

### Example(s):

Assume: Feathers( $x$ ):  $x$  has feathers,  $x \in \text{Animals}$   
Bird( $x$ ):  $x$  is a bird,  $x \in \text{Animals}$

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# Relational Calculi: Ideas

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Relational Calculi are “what, not how” languages

There are two forms, each with the same expressive power:

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## Tuple Relational Calculus: Background (1 / 2)

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- Proposed by Codd in 1972
- Abbreviated as “TRC”
- So named because the variables in TRC represent tuples
- TRC queries have this basic form:

where:

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# Tuple Relational Calculus: Background (2 / 2)

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Where are quantifiers (  $\exists$  and/or  $\forall$  ) used in Rel. Calc.?

- We quantify (bind) all tuple variables that do not appear on the left of the ‘such that’ (  $|$  ) symbol
- Most queries only use  $\exists$  (because most queries are asking if appropriate data *exists* in the DB)
- $\forall$  is used for “find X that are matched with all Y” queries
  - We will avoid such queries in relational calculus  
(Why? In Rel. Calc., they’re really messy.)
  - But we will deal with them in upcoming languages!

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## TRC: Query #1

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**Question:** What is the content of the Employee Relation?

Recall these schemas:

DEPARTMENT	<u>DeptNum</u>	DeptName	ManagerID	ManagerStartDate	
EMPLOYEE	Surname	GivenName	<u>EmpNum</u>	DeptID	Salary

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## TRC: Query #2

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**Question:** What are the names and salaries of the people in department #5?

DEPARTMENT	<u>DeptNum</u>	DeptName	ManagerID	ManagerStartDate	
EMPLOYEE	Surname	GivenName	<u>EmpNum</u>	DeptID	Salary

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## TRC: Query #3

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**Question:** What are the names of the parts that can be supplied by individual suppliers in quantity  $> 200$ ?

S	<u>S#</u>	Sname	Status	City	
P	<u>P#</u>	Pname	Color	Weight	City
SP	<u>S#</u>	<u>P#</u>	Qty		

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# TRC: Query #4

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**Question:** What are the names of the active suppliers of nuts?

S	<u>S#</u>	Sname	Status	City	
P	<u>P#</u>	Pname	Color	Weight	City
SP	<u>S#</u>	<u>P#</u>	Qty		

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## Aside: Expression Safety

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**Definition: Expression Safety**

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**Example(s):**

# Domain Relational Calculus (DRC): Bkgd.

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- Proposed by Lacroix and Pirotte in 1977 to supply a formalism for IBM's Query By Example (QBE) product.
- In DRC, a variable represents just one field of a tuple
- DRC queries have this basic form:

where:

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## DRC Query #1

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**Question:** What is the content of the Employee Relation?

Note the helpful field labels! ↓↓

	a	b	c	d	
DEPARTMENT	<u>DeptNum</u>	DeptName	ManagerID	ManagerStartDate	
	e	f	g	h	i
EMPLOYEE	Surname	GivenName	<u>EmpNum</u>	DeptID	Salary

## DRC Query #2

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**Question:** What are the names and salaries of the people in department #5?

	a	b	c	d	
DEPARTMENT	<u>DeptNum</u>	DeptName	ManagerID	ManagerStartDate	
	e	f	g	h	i
EMPLOYEE	Surname	GivenName	<u>EmpNum</u>	DeptID	Salary

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## DRC Query #3

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**Question:** What are the names of the parts that can be supplied by individual suppliers in quantity  $> 200$ ?

	j	k	l	m	
S	<u>S#</u>	Sname	Status	City	
	n	o	p	q	r
P	<u>P#</u>	Pname	Color	Weight	City
	s	t	u		
SP	<u>S#</u>	<u>P#</u>	Qty		

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## DRC Query #4 (1 / 2)

**Question:** What are the names of the active suppliers of nuts?

S	j	k	l	m
	<u>S#</u>	Sname	Status	City

P	n	o	p	q	r
	<u>P#</u>	Pname	Color	Weight	City

SP	s	t	u
	<u>S#</u>	<u>P#</u>	Qty

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## DRC Query #4 (2 / 2) — Alternate Join Option

**Question:** What are the names of the active suppliers of nuts?

$$\{ \langle k \rangle \mid (\exists j l) (\langle j k l m \rangle \in S \wedge l > 0 \wedge$$
$$(\exists t) (\langle \boxed{j} t u \rangle \in SP \wedge \boxed{A s = j}) \wedge$$
$$(\exists o) (\langle \boxed{t} o p q r \rangle \in P \wedge \boxed{A t = n} \wedge o = \text{'Nut'})) \}$$

(We copied vars and eliminated the corresponding conditions.)

S	j	k	l	m
	<u>S#</u>	Sname	Status	City

P	n	o	p	q	r
	<u>P#</u>	Pname	Color	Weight	City

SP	s	t	u
	<u>S#</u>	<u>P#</u>	Qty

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