# The Key Concepts and Steps in Data Science

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Statistics Discipline

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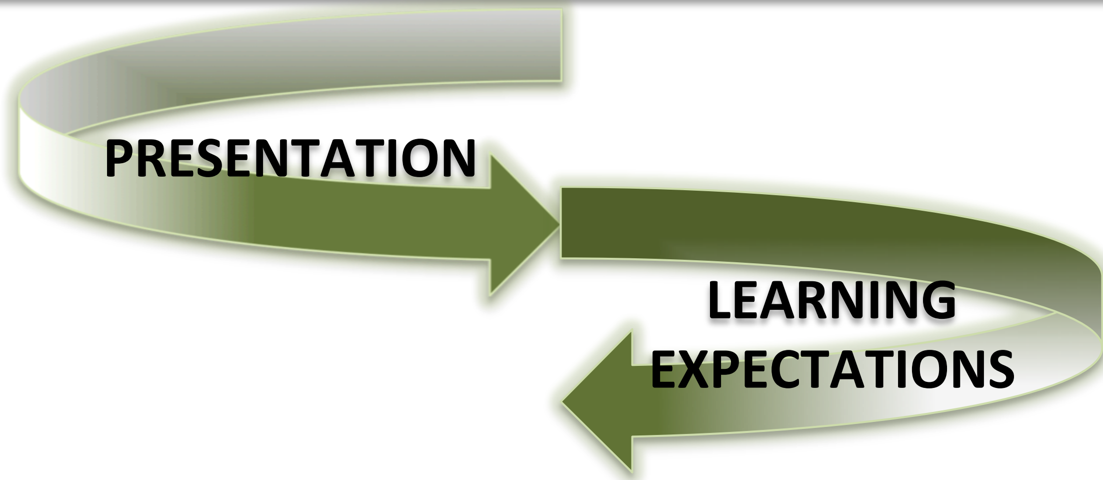
# OUTLINE





- INTRODUCTIONS & BACKGROUND INFORMATION
- STEPS/STAGES OF DATA SCIENCE/STATISTICS
  - QUESTION/PROBLEM
  - DATA COLLECTION
  - DATA MANIPULATIONS
  - EXPLORATORY DATA ANALYSIS
  - COMFIRMATORY DATA ANALYSIS
  - COMMUNICATING THE FINDINGS
  - FORMULATING NEW QUESTIONS/PROBLEMS
- GENERAL REMARKS

# LEARNING OBJECTIVES

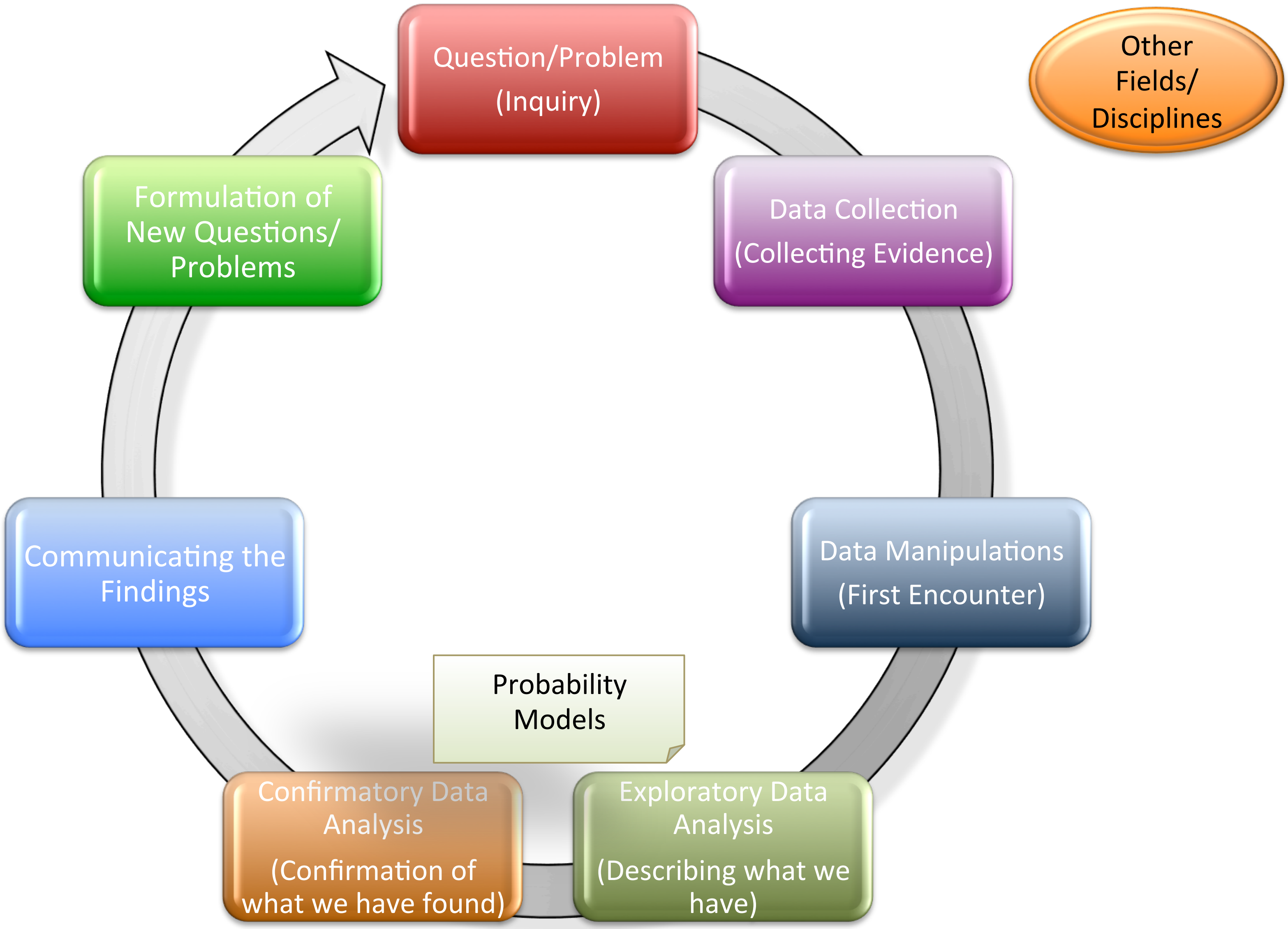
## PRESENTATION

- LEARN MOST RECENT TRENDS IN DATA ANALYSIS
- IDENTIFY THE SEVEN STAGES OF THE DATA SCIENCE (you)
- LEARN COMMON CONCEPTS IN EACH (you)
- GET FAMILIAR WITH SOME STATISTICAL TECHNIQUES/METHODS/TOOLS THAT ARE AVAILABLE (you)
- SEE AN EXAMPLE OF A TYPICAL LECTURE

## LEARNING EXPECTATIONS

- LEARN ABOUT WHAT LEARNERS KNOW ABOUT DATA SCIENCE (me)
- UNDERSTAND THEIR EXPECTATIONS (me)
- LEARN ABOUT THE LEARNERS BACKGROUND AND FUTURE PLANS (me))
- ANSWER LEARNERS' QUESTIONS ON STATISTICS, DATA SCIENCE, AND TEACHING AND LEARNING PROCESS IN USA (me)

# STAGES OF DATA SCIENCE



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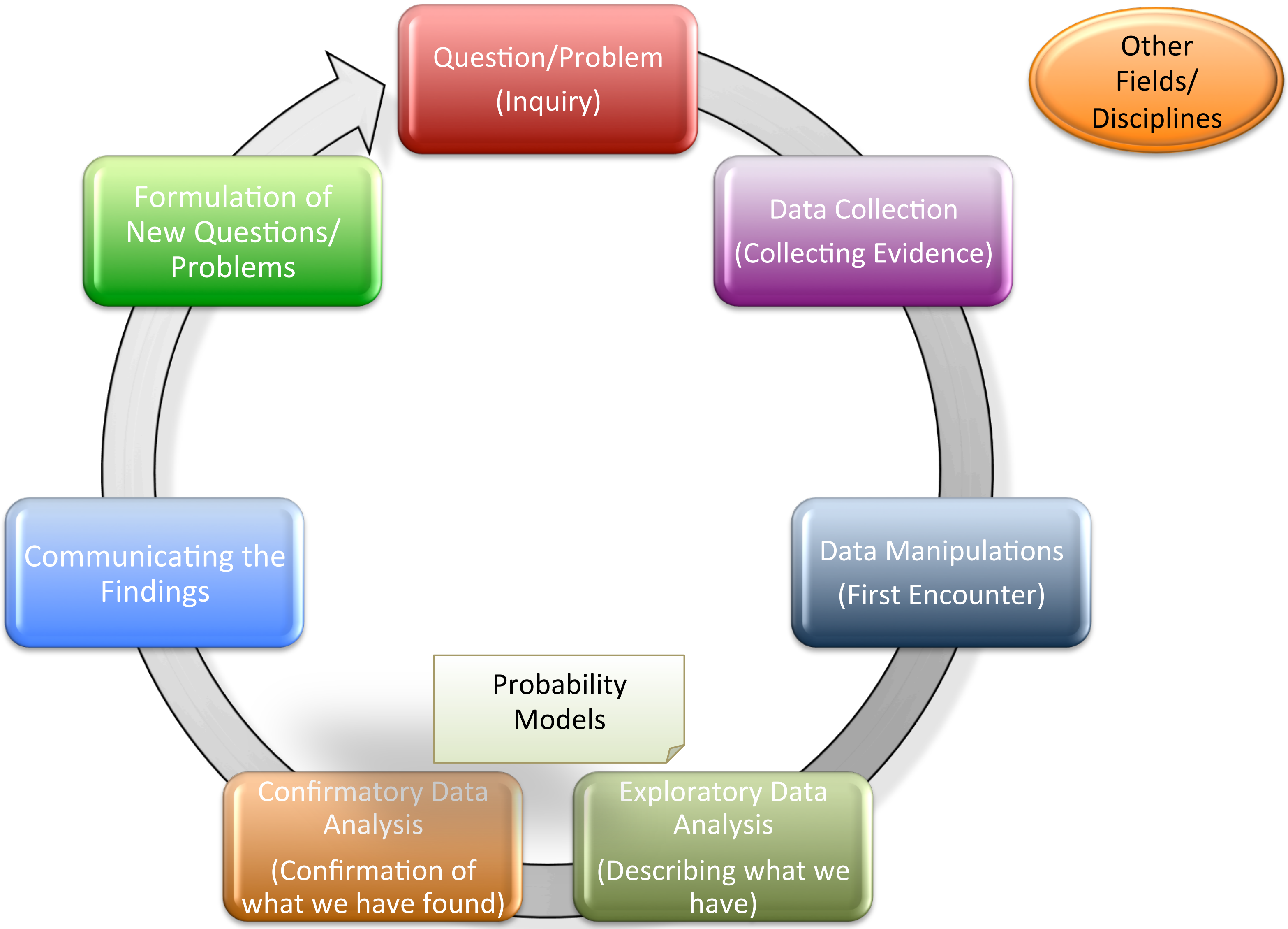

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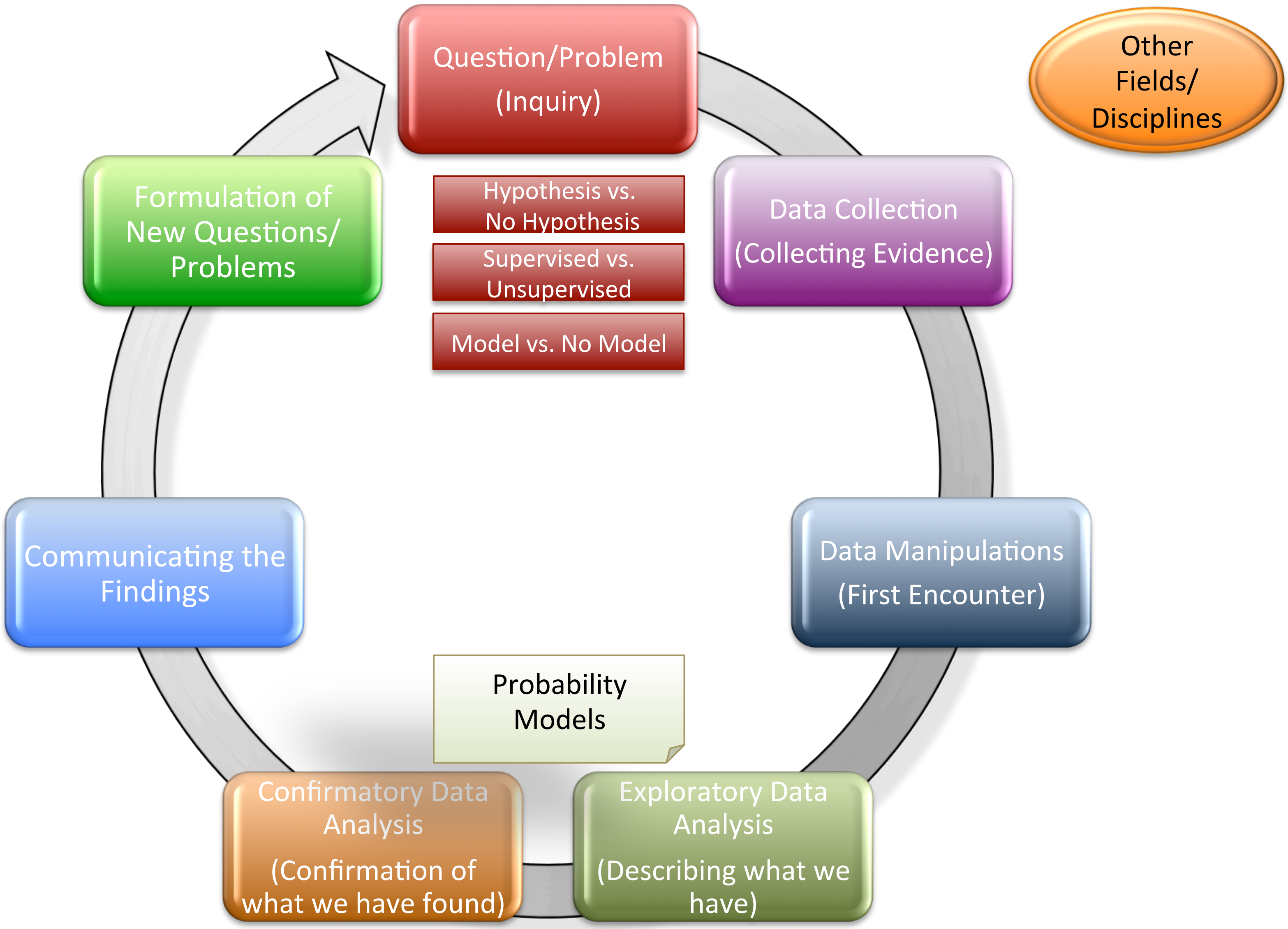

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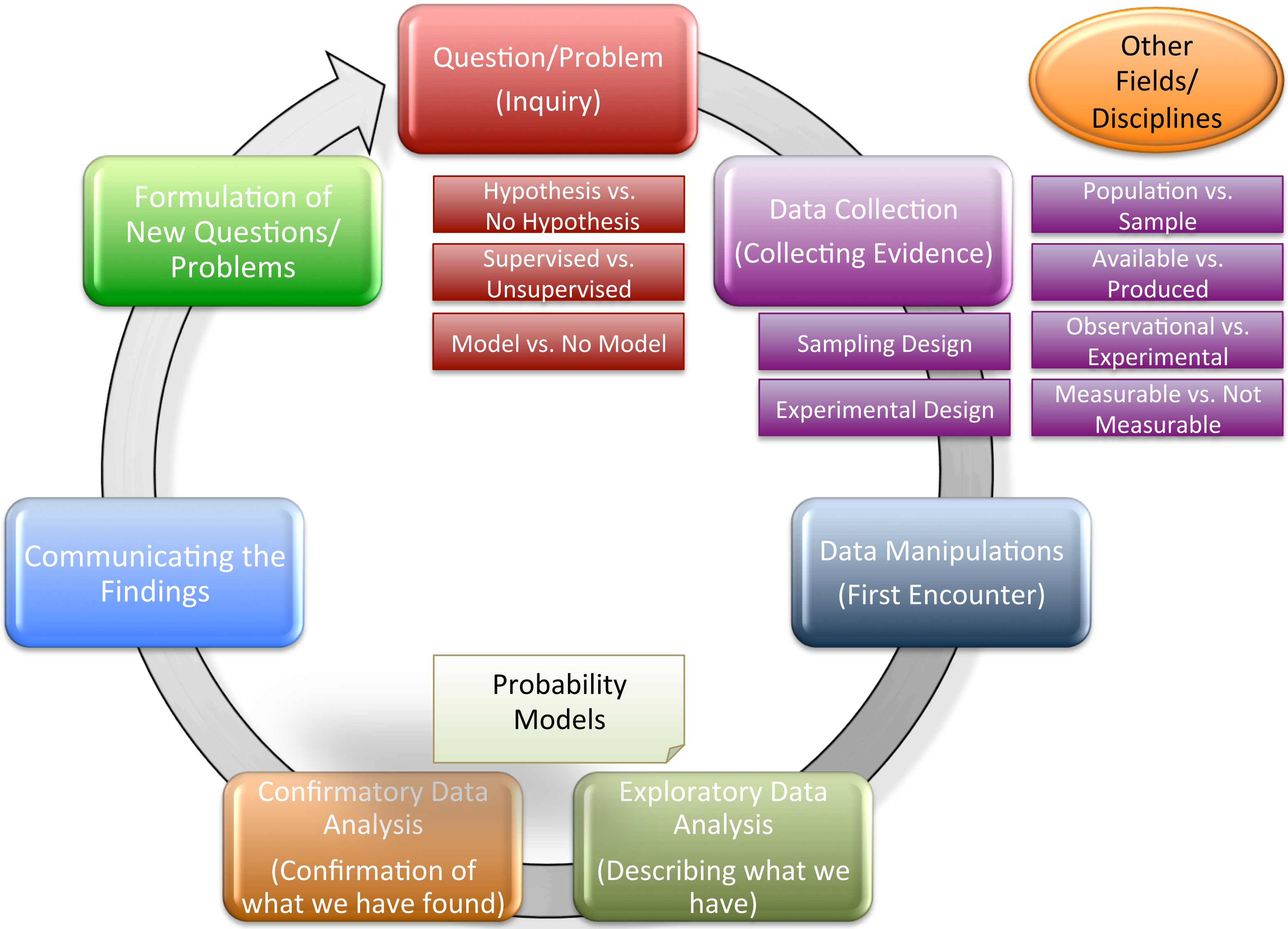

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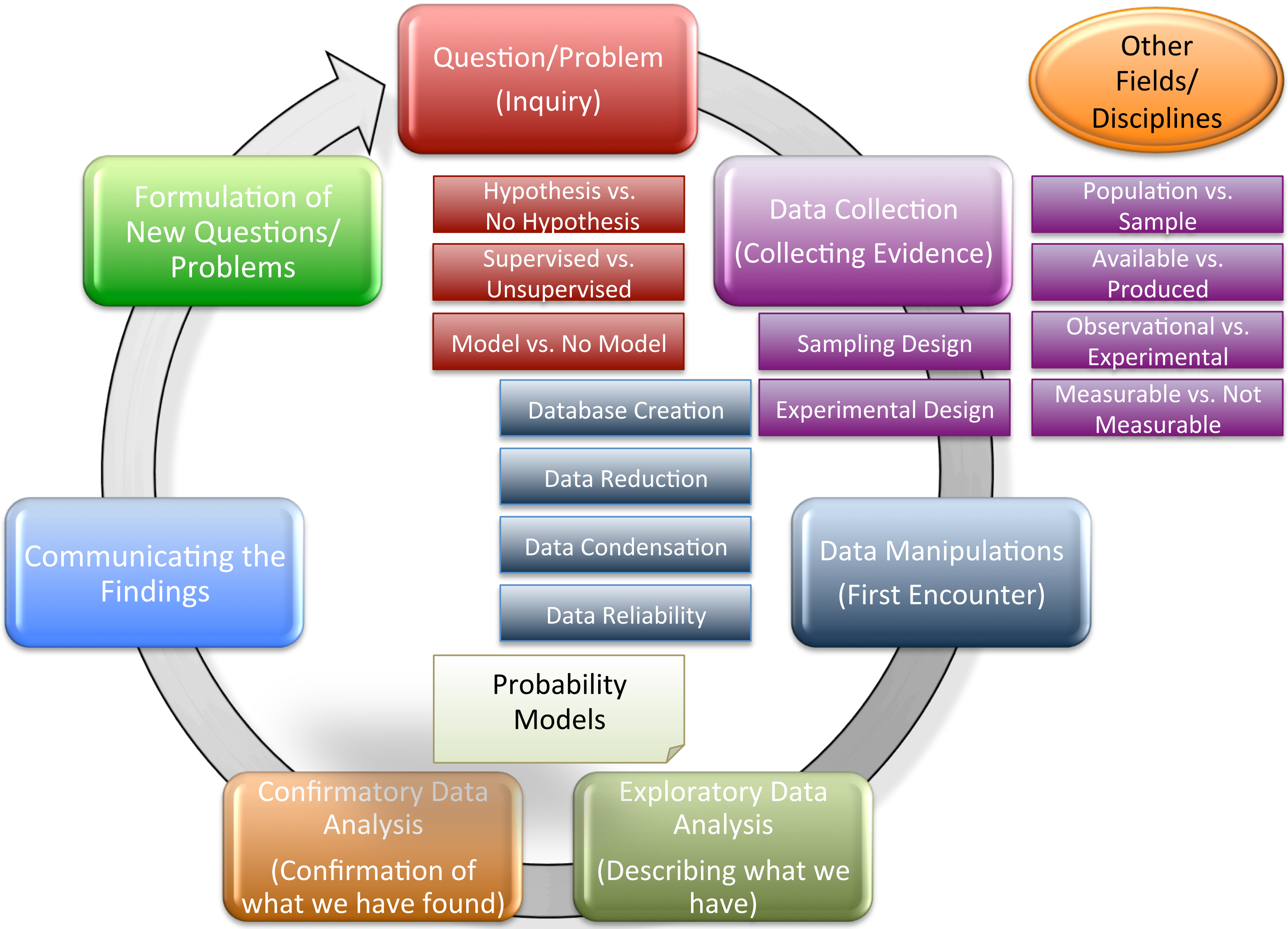

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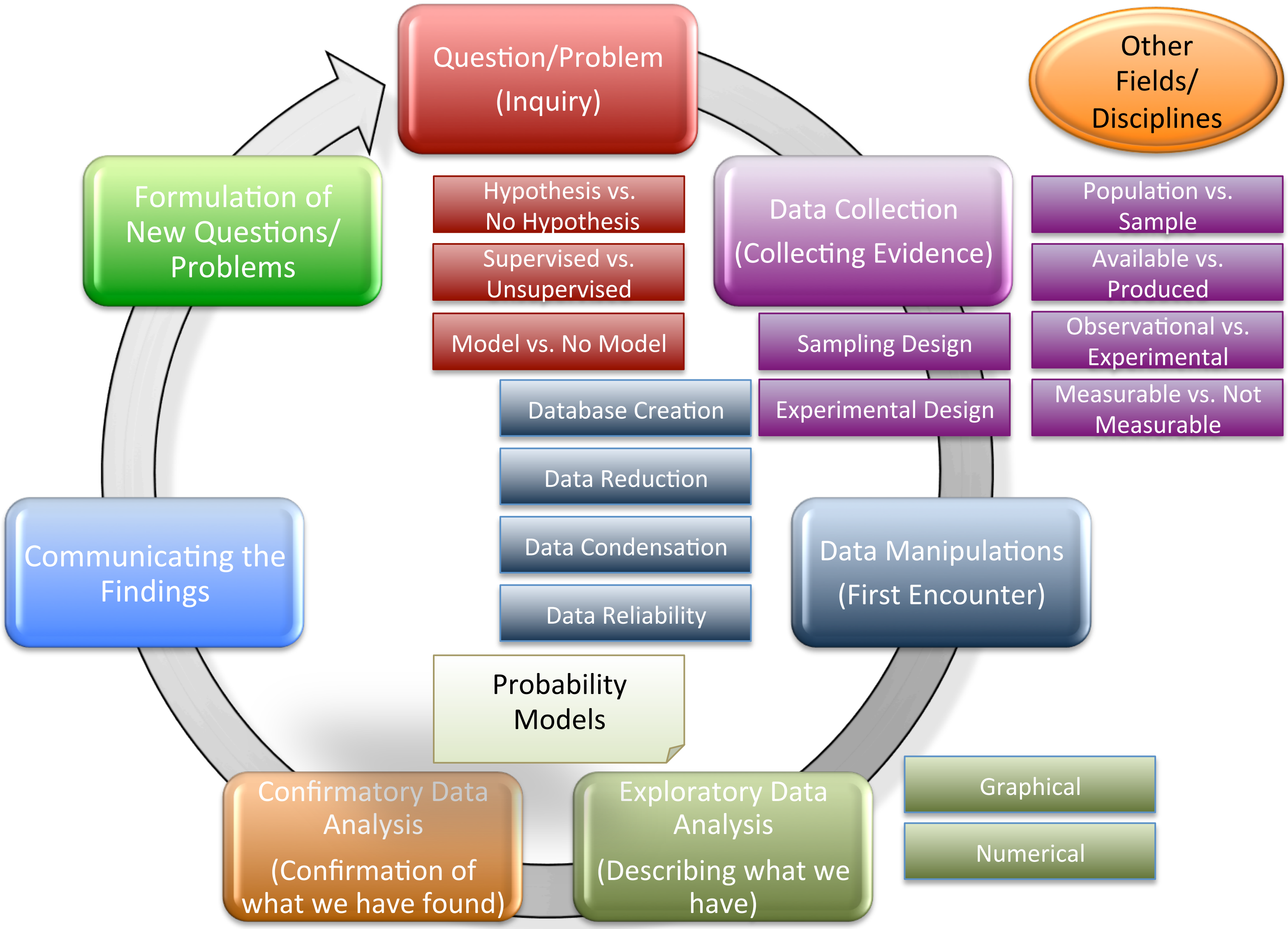

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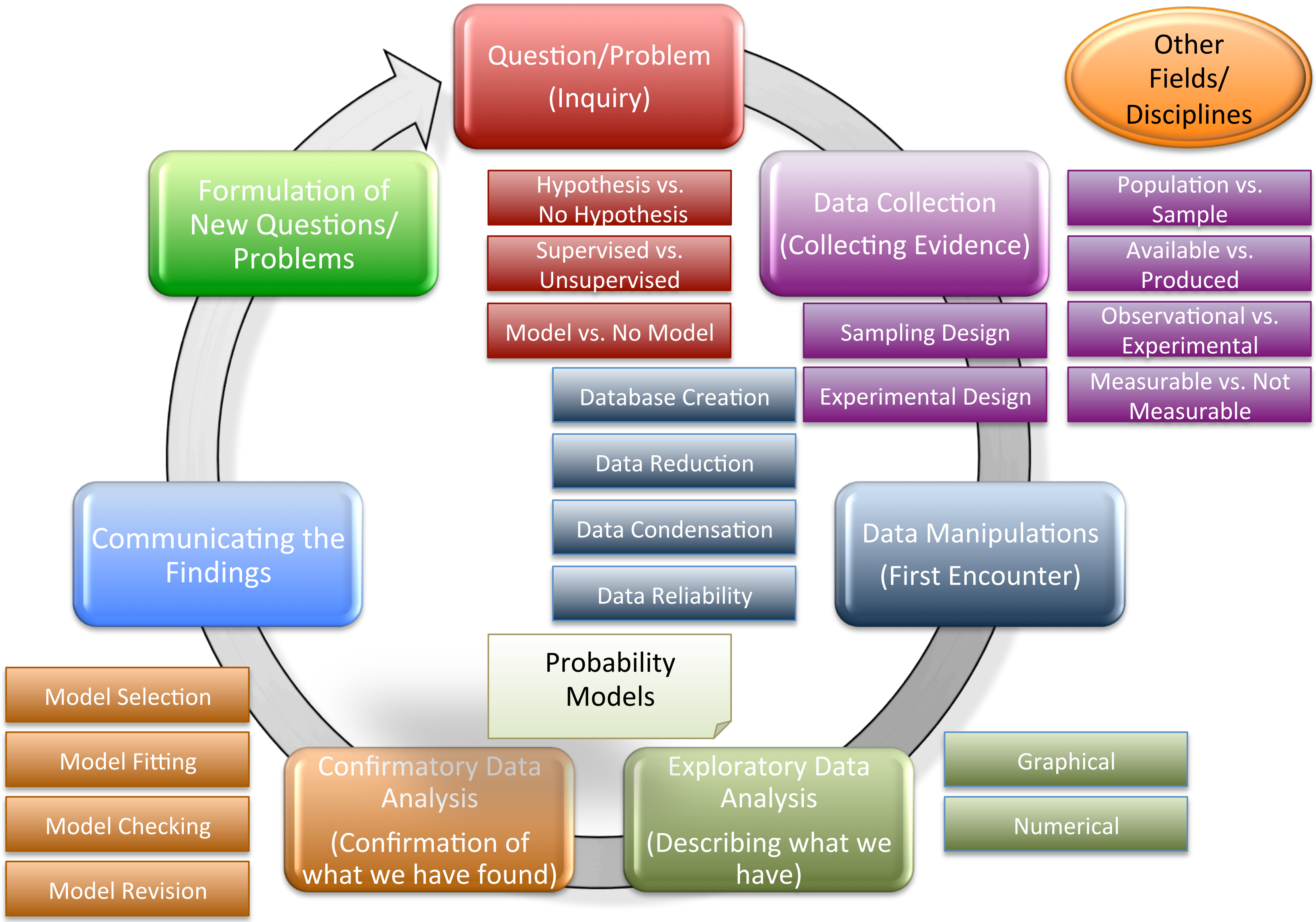

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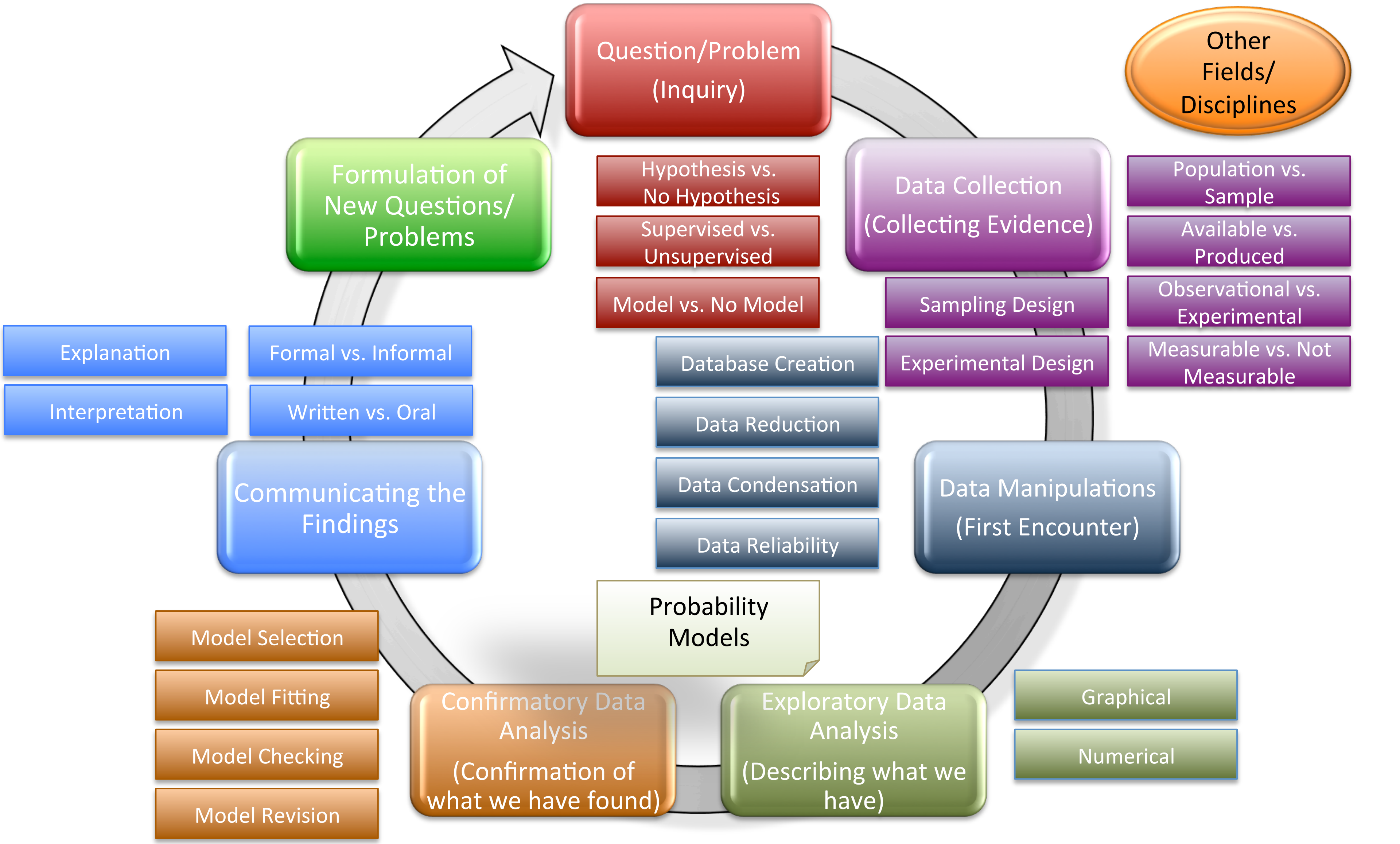

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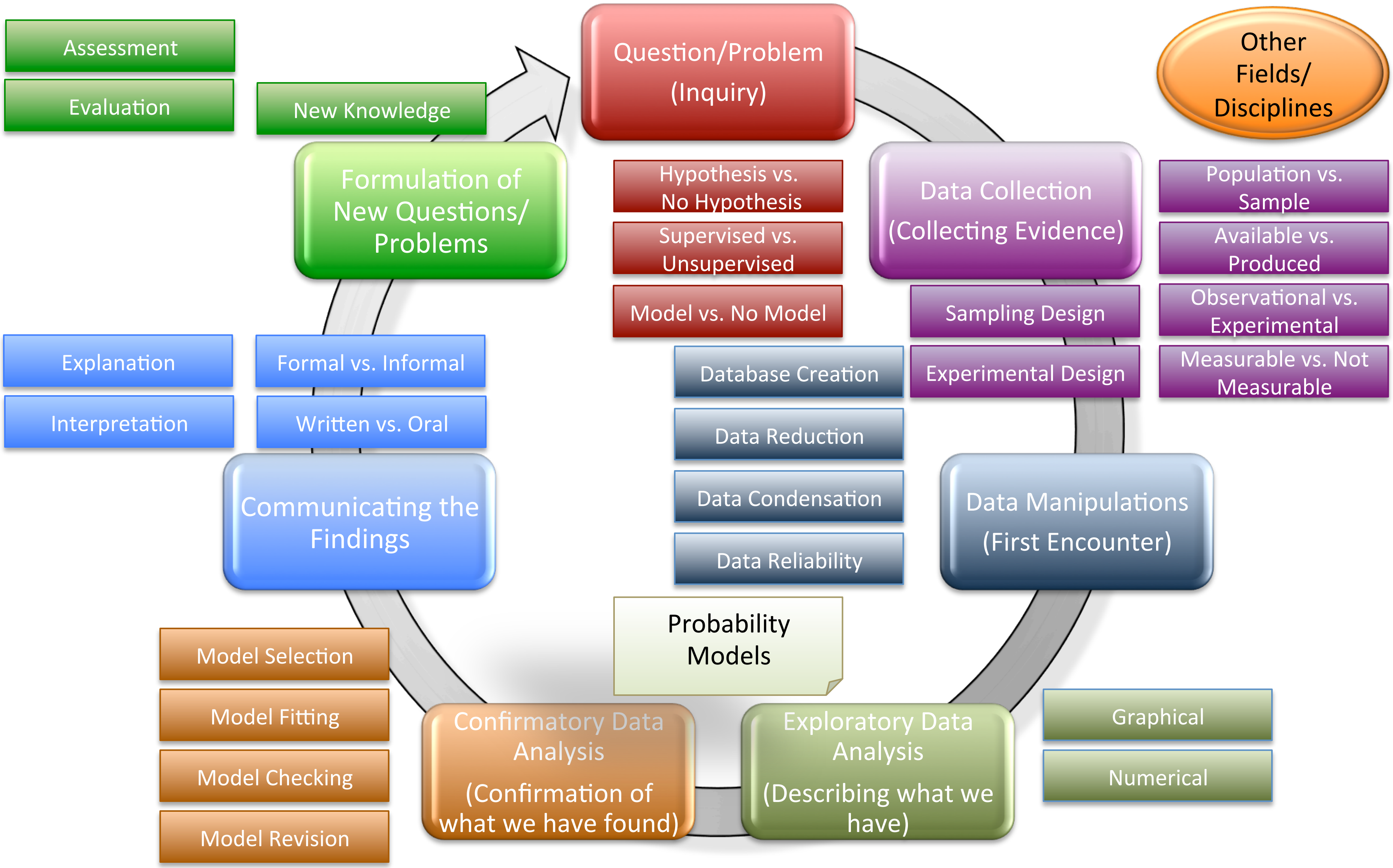
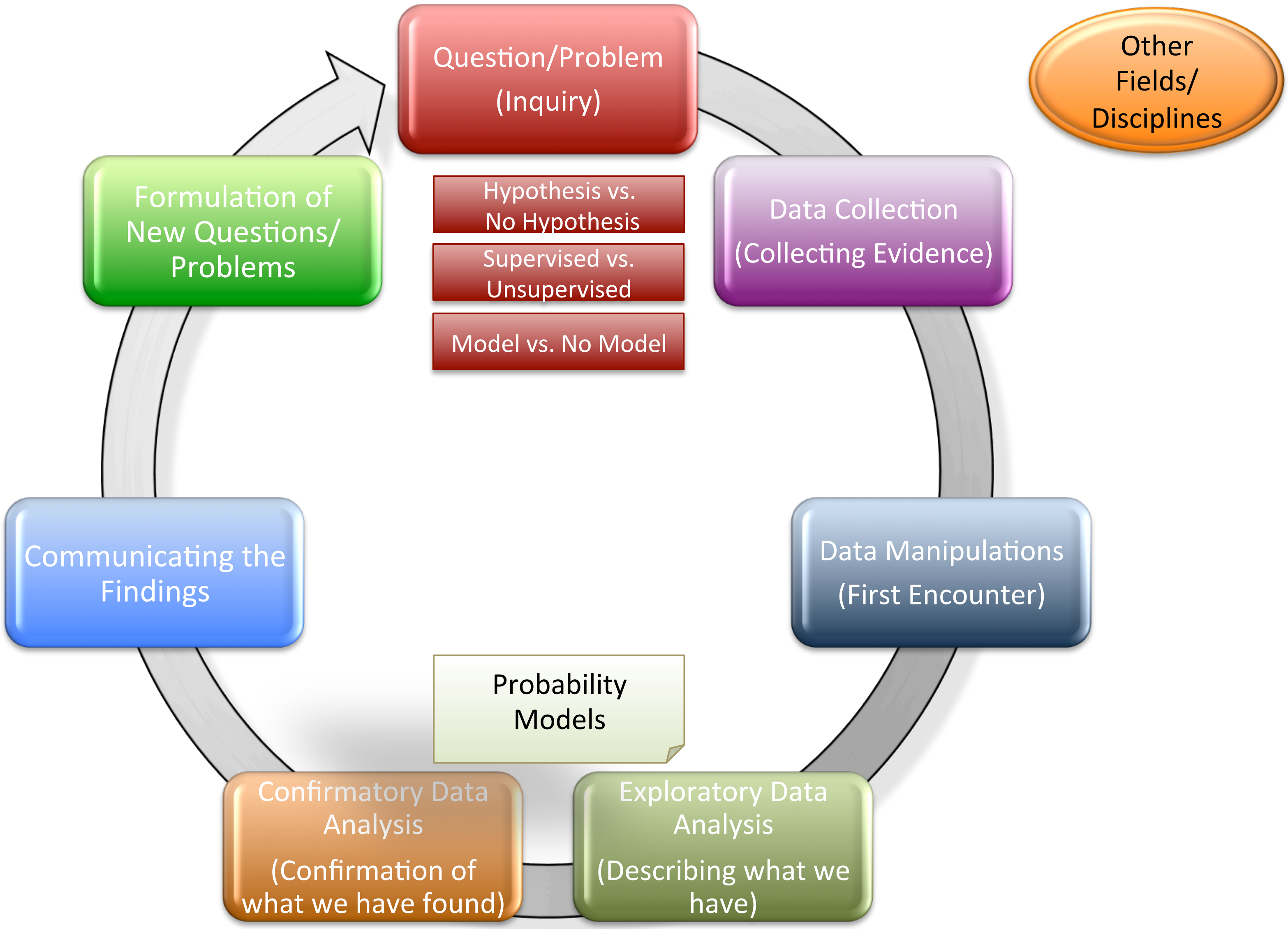


# QUESTION/PROBLEM



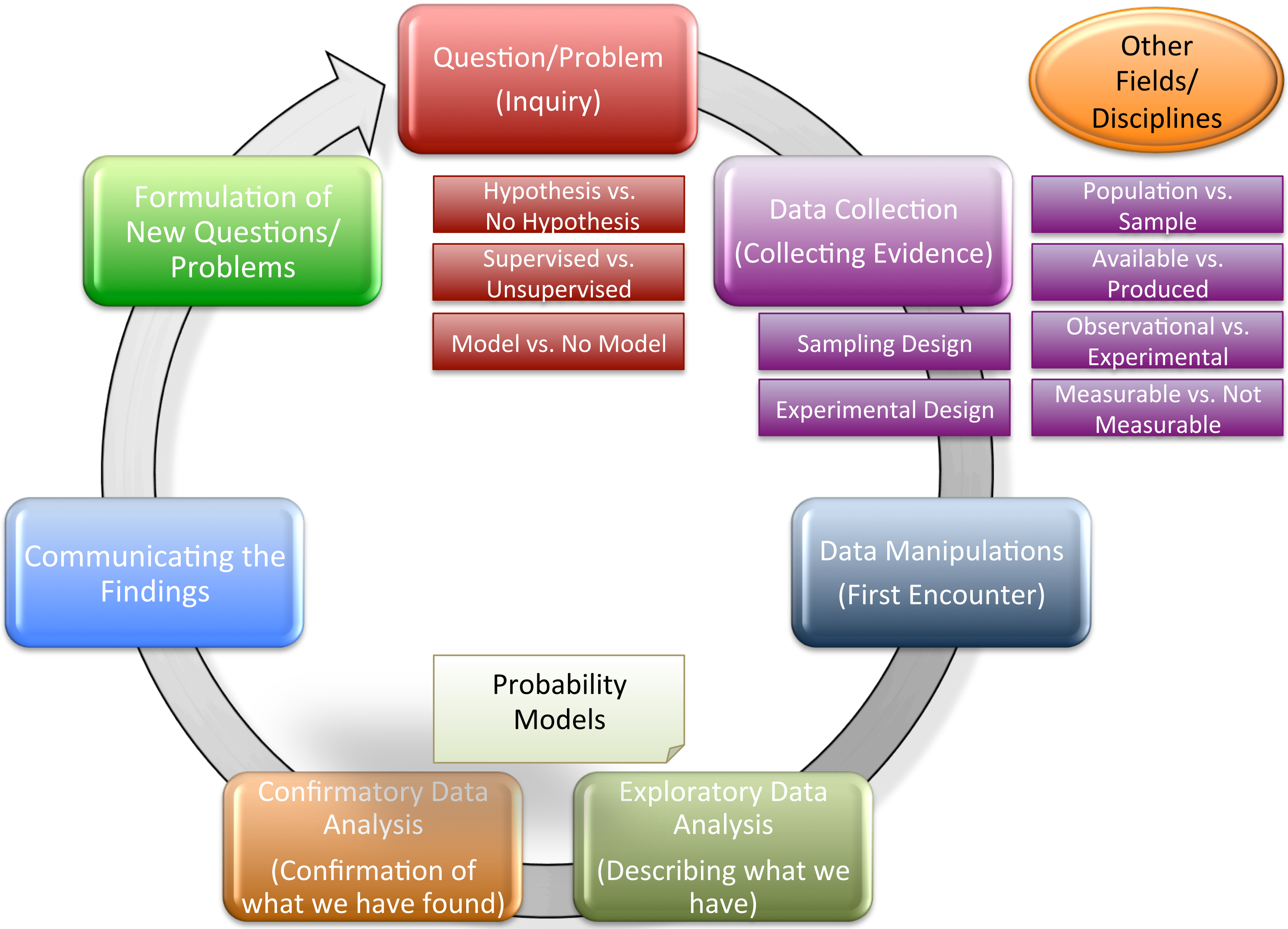
# QUESTION/PROBLEM

| EXPLORATORY/DESCRIPTIVE MULTIVARIATE ANALYSIS | CONFIRMATORY/INFERENTIAL MULTIVARIATE ANALYSIS |
|---|---|
| DATA MINING | DATA CRAFTING |
| DATA EXPLORATION<br>PATTERN RECOGNITION | STATISTICAL INFERENCE |
| LOOKING FOR PATTERNS | TEST HYPOTHESES |
| EXPLORING RELATIONSHIPS | FIT & TEST THE MODELS |
| FORM HYPOTHESES | |
| SELECT MODELS | |

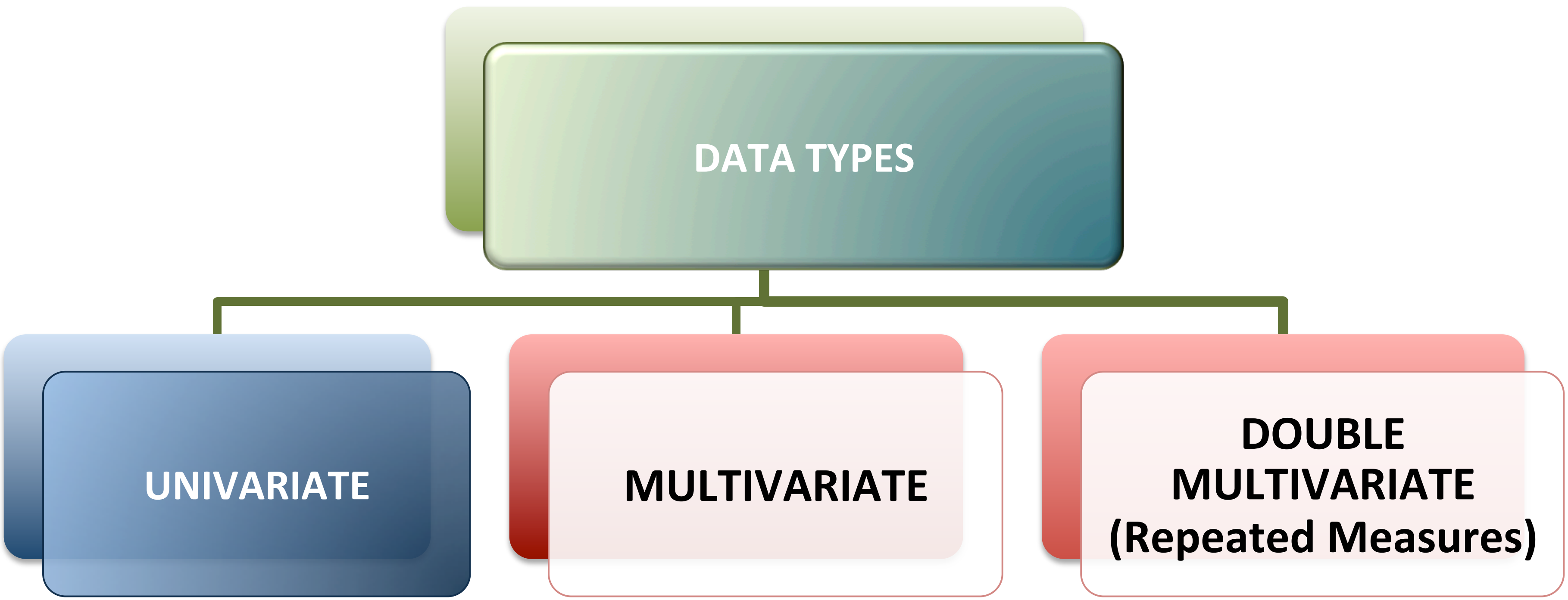
# QUESTION/PROBLEM

| PATTERN RECOGNITION | | |
|---|---|---|
| | UNSUPERVISED (NO PRIOR KNOWLEDGE) | SUPERVISED ( PRIOR KNOWLEDGE) |
| PATTERNS OF "SIMILARITY" BETWEEN VARIABLES | ORDINATION<br>PCA<br>FACTOR ANALYSIS | DISCRIMINANT ANALYSIS<br>GLM<br>REGRESSION<br>PATH ANALYSIS |
| PATTERNS OF "SIMILARITY" BETWEEN INDIVIDUALS | ORDINATION<br>PRINCIPAL COMPONENT ANALYSIS<br>MDS<br>CLUSTER ANALYSIS | |

# DATA COLLECTION



# DATA COLLECTION: DATA TYPES



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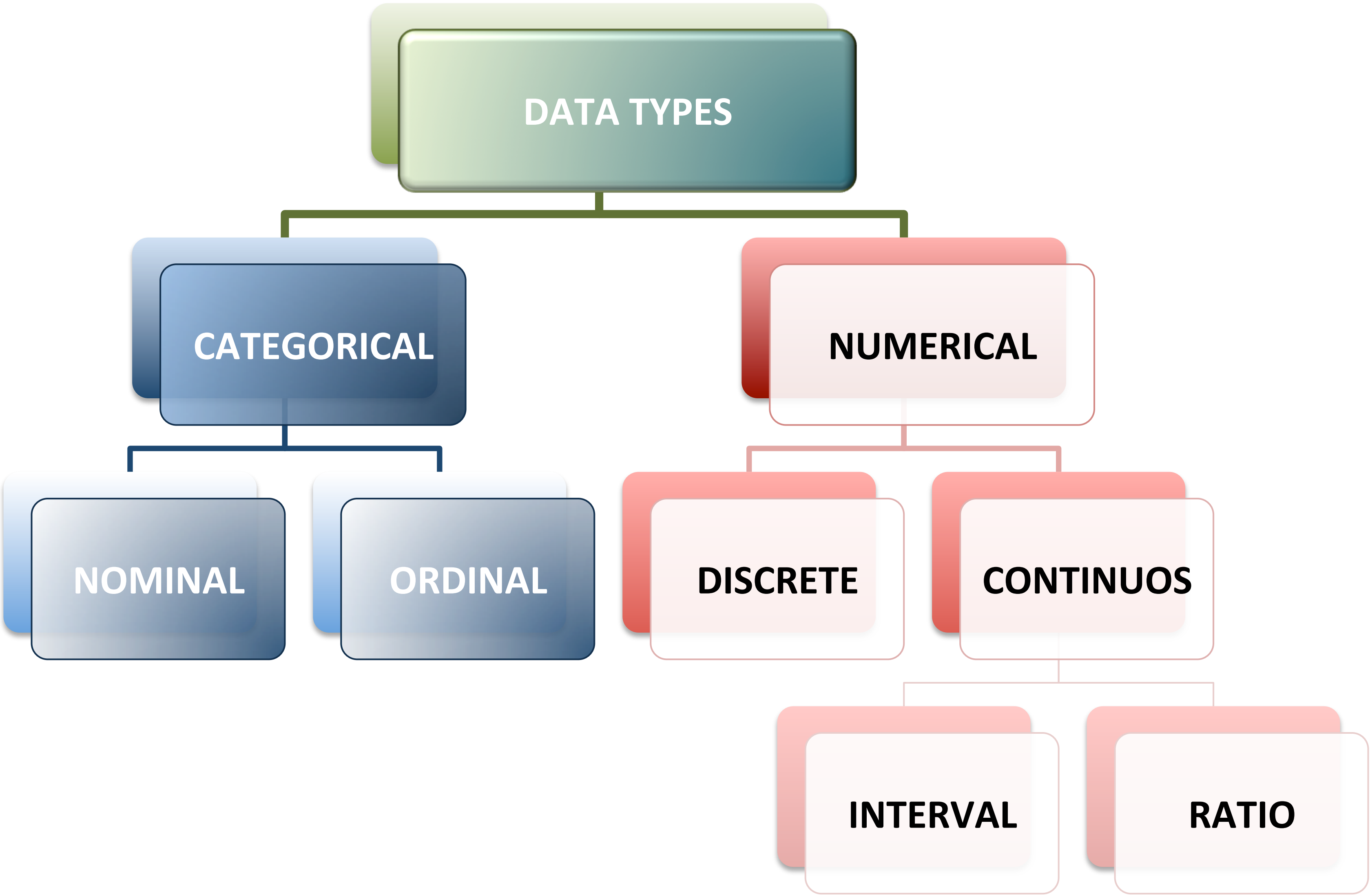


# DATA COLLECTION: DATA TYPES

| | | Response Variable | |
|---|---|---|---|
| | | Categorical (Nominal or Ordinal) | Numerical (Interval or Ratio) |
| Explanatory Variable | Categorical (Nominal or Ordinal) | | |
| | Numerical (Interval or Ratio) | | |

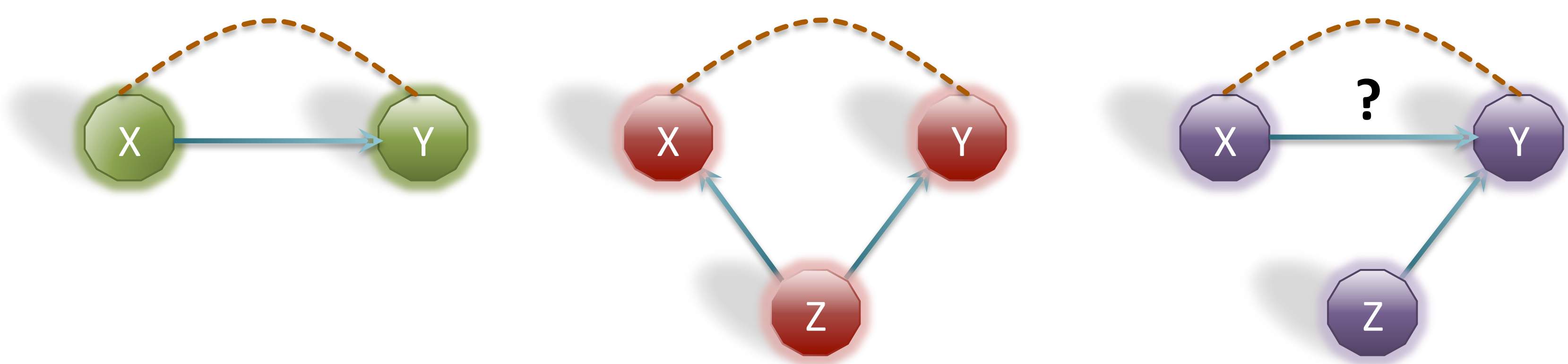
# DATA COLLECTION: DATA TYPES

| | | Response Variable | |
|---|---|---|---|
| | | Categorical (Nominal or Ordinal) | Numerical (Interval or Ratio) |
| Explanatory Variable | Categorical (Nominal or Ordinal) | Chi-square Analysis Through Crosstabulation | Independent/ Dependent t-test<br><br>ANOVA |
| | Numerical (Interval or Ratio) | Logistic Regression<br><br>Log-linear Models | Regression<br><br>Correlation |

# DATA COLLECTION: TYPES OF RELATIONSHIPS

Association/Correlation does not imply Causation
Dependence does not imply Causation

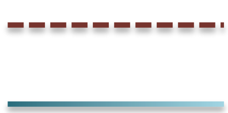
(but it sure is a hint Lynd & Stevenson (2007), Tufte (2006), von Eye & DeShon (2011)).




CAUSAL

COMMON RESPONSE

CONFOUNDING



Association/Correlation

Cause-and-effect Relationship

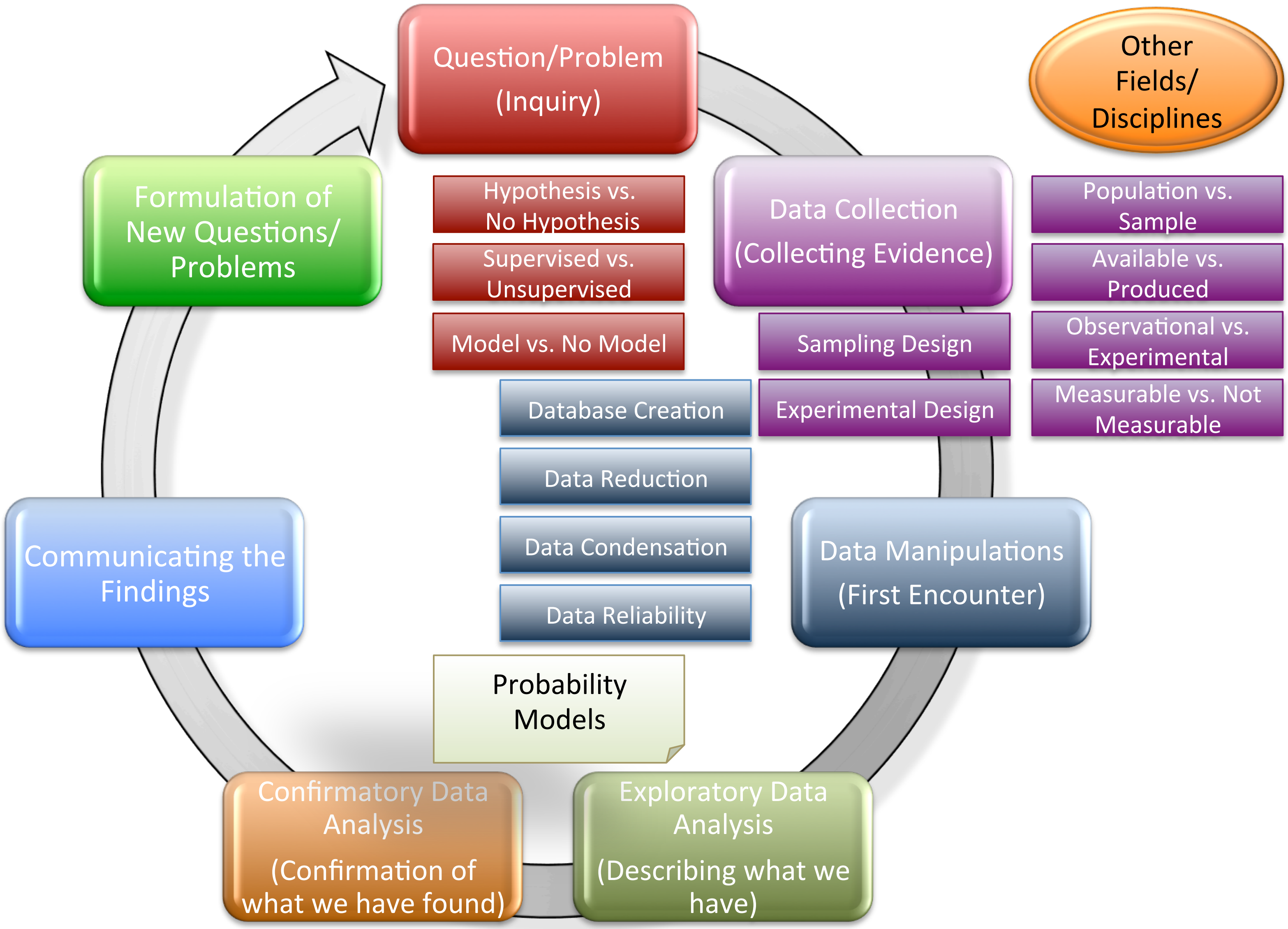
# DATA COLLECTION: DESIGN OF EXPERIMENTS

Causal relationships can only be set through experiments.

## PRINCIPALS OF DESIGN OF EXPERIMENTS

- CONTROL
- RANDOMIZE
- REPLICATE

# DATA MANIPULATIONS



# DATA MANIPULATIONS: DATA RELIABILITY

*Data reliability is a state that exists when data is sufficiently complete and error free to be convincing for its purpose and context.*

- **COMPLETE:** Includes all of the data elements (variables/fields) needed for the analysis
- **ACCURATE:**
  - **CONSISTENT:** The data was obtained and used in a manner that is clear and well-defined enough to yield similar results in similar analysis
  - **CORRECT:** The data set reflects the data entered at the source and/or properly represents the intended results.
- **UNALTERED:** The data reflects source and has not been tampered with.

# DATA MANIPULATIONS: DATABASE

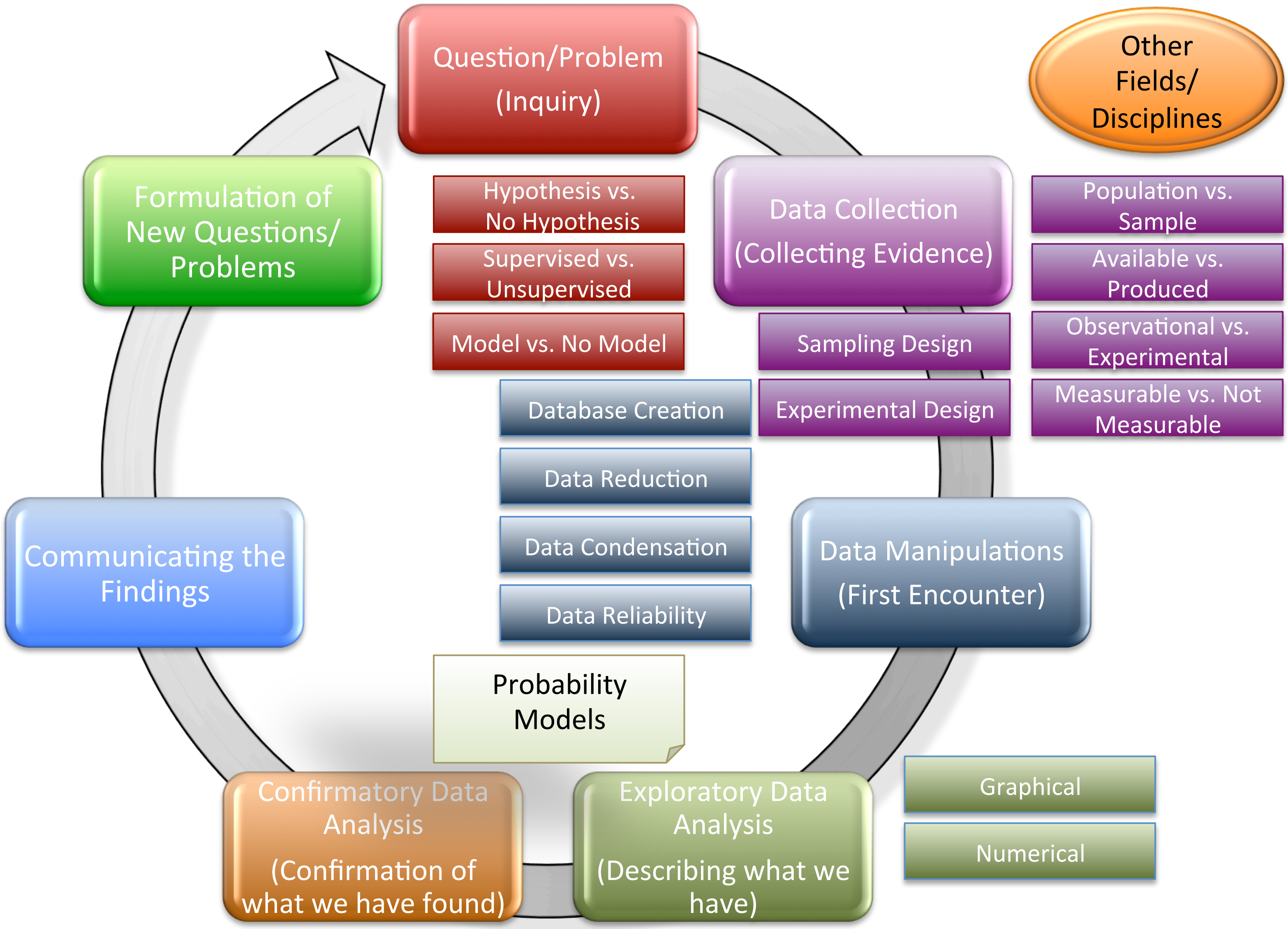
*Database is an organized collection of data*

- Easy to use (data entry and data manipulations)
- Dynamic
- Interactive
- Open to collaboration
- Integrated

- Piece of paper
- Word processor (Microsoft Word)
- Microsoft Excel
- Microsoft Access
- Statistical software package (R, StatCrunch, SPSS, SAS etc.)
- Any program that uses SQL (Structured Query Language)
- Google Docs
- Google Fusion Tables

(UMM Data Services Center: http://mnstats.morris.umn.edu/UMMDataServicesCenter.html )

# EXPLORATORY DATA ANALYSIS

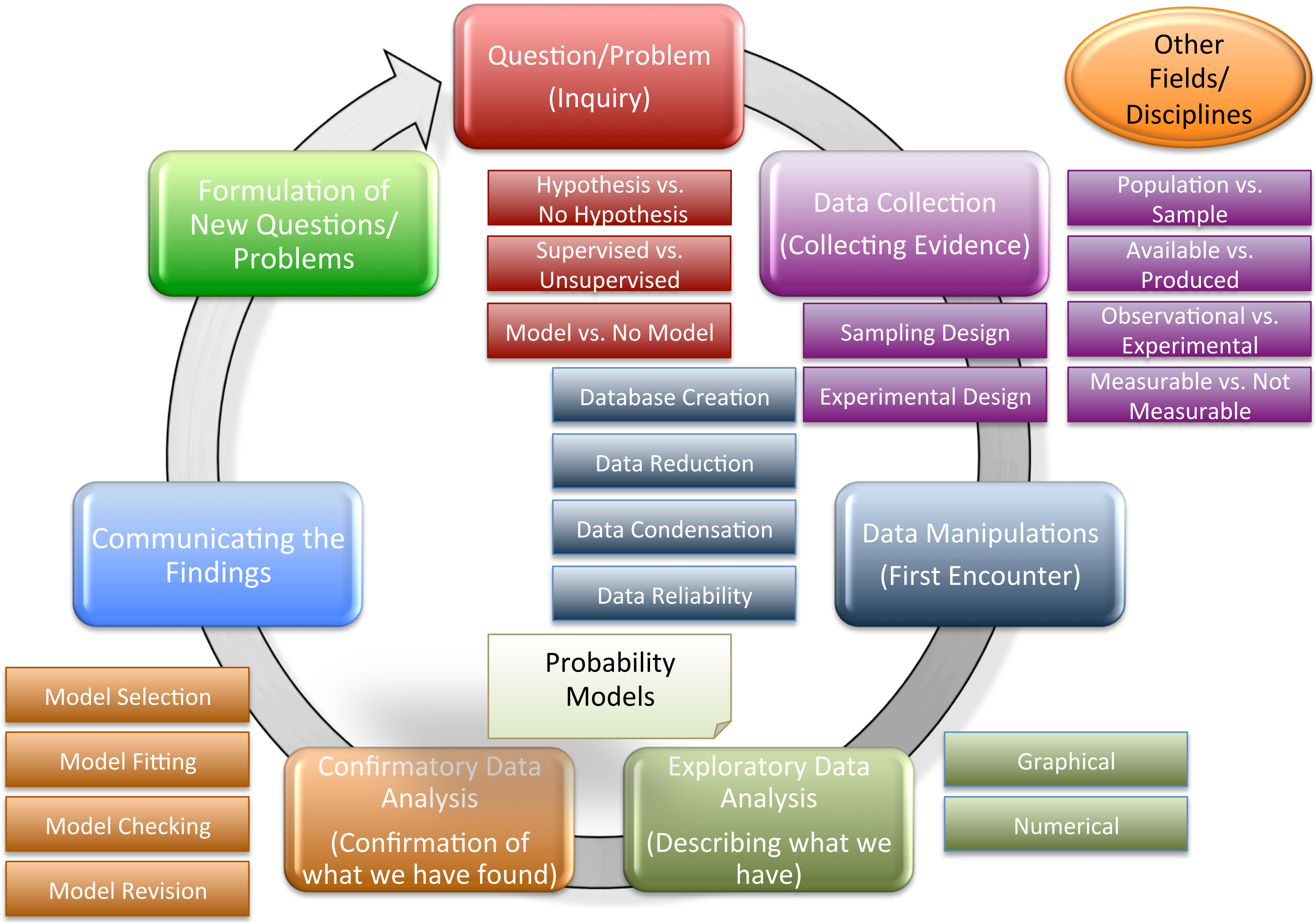


# EXPLORATORY DATA ANALYSIS

- Dynamic
- Interactive
- Database integrated graphical displays

Correct selection of numerical and graphical summary techniques and methods

# CONFIRMATORY DATA ANALYSIS



# CONFIRMATORY DATA ANALYSIS

$$Y_1, Y_2, \ldots, Y_n \text{ are i.i.d. from } \mathrm{N}\left(\mu, \sigma^2\right)$$

$$Y_1, Y_2, \ldots, Y_n \Rightarrow DATA$$

i.i.d. $\Rightarrow$ independent and identically distributed

$\Rightarrow$ Simple random sample from the same population

$$\mathrm{N}\left(\mu, \sigma^2\right) \Rightarrow \text{Normal Distribution}$$

$$Y_1, Y_2, \ldots, Y_n \text{ are i.i.d. from } \mathrm{N}\left(\beta_0 + \sum_{i=1}^{p} \beta_i \mu_{X_i}, \sigma^2\right)$$

$\beta_0 + \sum_{i=1}^{p} \beta_i \mu_{X_i} \Rightarrow$ Linear Model $\mathrm{N}\left(\ldots, \sigma^2\right) \Rightarrow$ Constant Variance

# CONFIRMATORY DATA ANALYSIS: TRANSFORMATIONS

WHAT TO DO WHEN THE MODEL ASSUMPTIONS ARE VIOLATED?

FEWER ASSUMPTIONS

TRANSFORMATIONS

ORIGINAL DATA

POWER TRANSFORMATION

RANKING

CATEGORIZING

NONPARAMETRIC/DISTRIBUTION FREE STATISTICS

LOSS OF INFORMATION

# CONFIRMATORY DATA ANALYSIS: NONPARAMETRIC STATISTICS

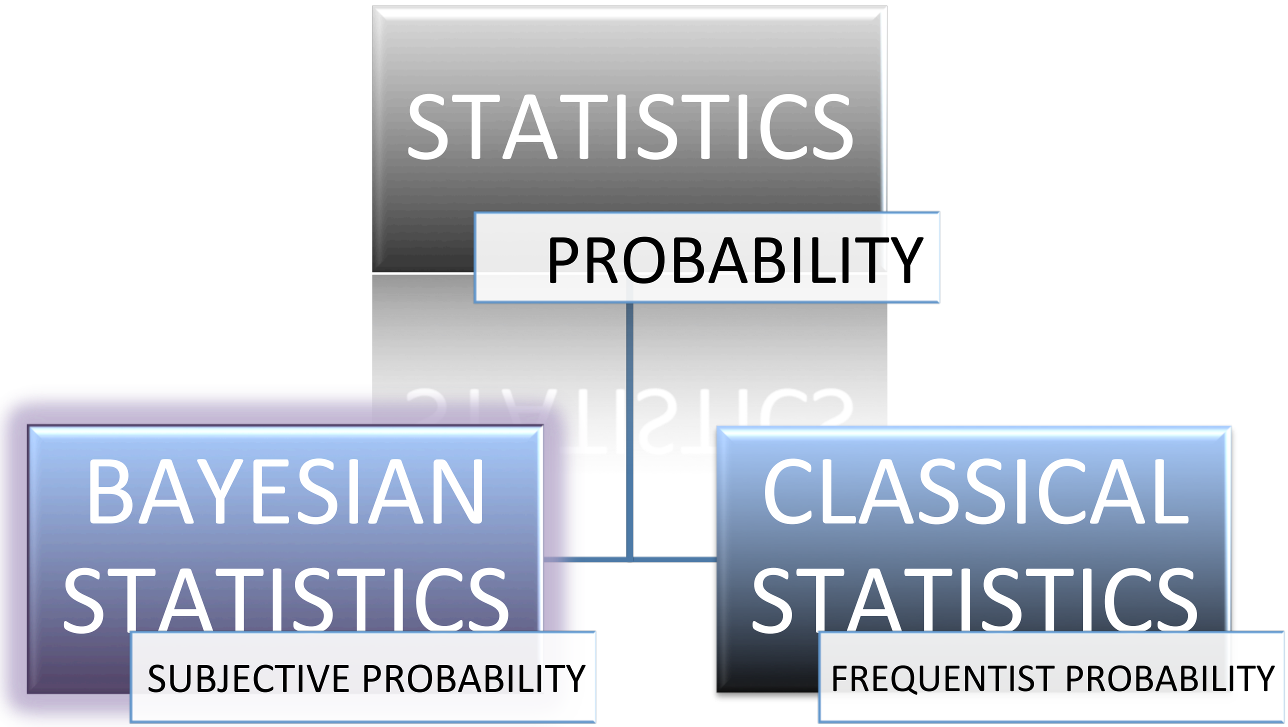
- RANK-BASED METHODS
- PERMUTATION TESTS

  *R.A. FISHER (1935)*
- BOOTSRAP METHODS

  *TAKE A SAMPLE OF SAME SIZE FROM THE SAMPLE WITH REPLACEMENT*
- CURVE SMOOTHING

  *NO LINEAR OR NONLINEAR MODEL*

# CONFIRMATORY DATA ANALYSIS



# CONFIRMATORY DATA ANALYSIS

*How would you describe in plain English the characteristics that distinguish Bayesian from Frequentist reasoning?*
(http://stats.stackexchange.com)

Here is how I would explain the basic difference to my grandma:
I have misplaced my phone somewhere in the home. I can use the phone locator on the base of the instrument to locate the phone and when I press the phone locator the phone starts beeping.

***Problem:*** Which area of my home should I search?

***Frequentist Reasoning:***

I can hear the phone beeping. I also have a **mental model** which helps me identify the area from which the sound is coming from. Therefore, upon hearing the beep, I infer the area of my home I must search to locate the phone.

***Bayesian Reasoning:***

I can hear the phone beeping. Now, apart from a **mental model** which helps me identify the area from which the sound is coming from, I also know the locations where I have misplaced the phone in the past. So, I combine my inferences using the beeps and my **prior information** about the locations I have misplaced the phone in the past to identify an area I must search to locate the phone.

# CONFIRMATORY DATA ANALYSIS

Tongue firmly in cheek:

A ***Bayesian*** defines a "probability" in **exactly the same way that most non-statisticians do** - namely an indication of the plausibility of a proposition or a situation. If you ask him a question, he will give you **a direct answer** assigning probabilities describing the plausibilities of the possible outcomes for the particular situation (and state his prior assumptions).

A ***Frequentist*** is someone that believes probabilities represent long run frequencies with which events occur; if needs be, he will **invent a fictitious population** from which your particular situation could be considered a random sample so that he can meaningfully talk about long run frequencies. If you ask him a question about a particular situation, he will **not give a direct answer**, but instead make a statement about this (possibly imaginary) population. Many non-frequentist statisticians will be easily **confused** by the answer and interpret it as Bayesian probability about the particular situation.

**P-VALUE? https://www.youtube.com/watch?feature=endscreen&NR=1&v=ax0tDcFkPic**
**https://www.youtube.com/watch?v=ez4DgdurRPg**

# CONFIRMATORY DATA ANALYSIS

*Very* crudely I would say that:

**Frequentist:** Sampling is infinite and decision rules can be sharp. Data are a **repeatable random sample** - there is a frequency**. Underlying parameters are fixed i.e. they remain constant during this repeatable sampling process**.

**Bayesian:** Unknown quantities are treated probabilistically and the **state of the world can always be updated.** Data are observed from the realised sample. Parameters are unknown and described probabilistically. **It is the data which are fixed**.

# CONFIRMATORY DATA ANALYSIS: SOME TECHNIQUES

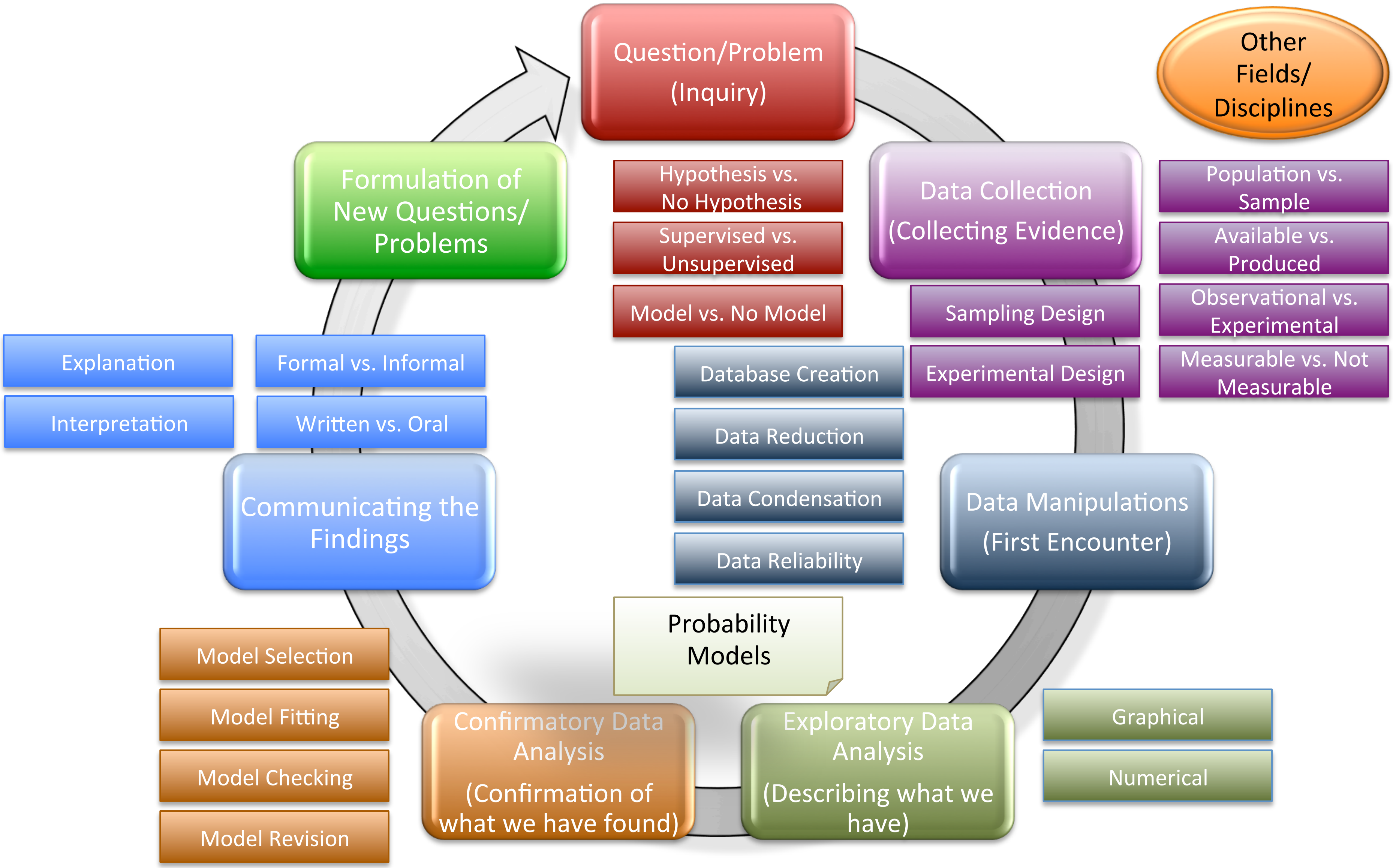
- **MULTIVARIATE TECHNIQUES**

http://mnstats.morris.umn.edu/multivariatestatistics/overview.html

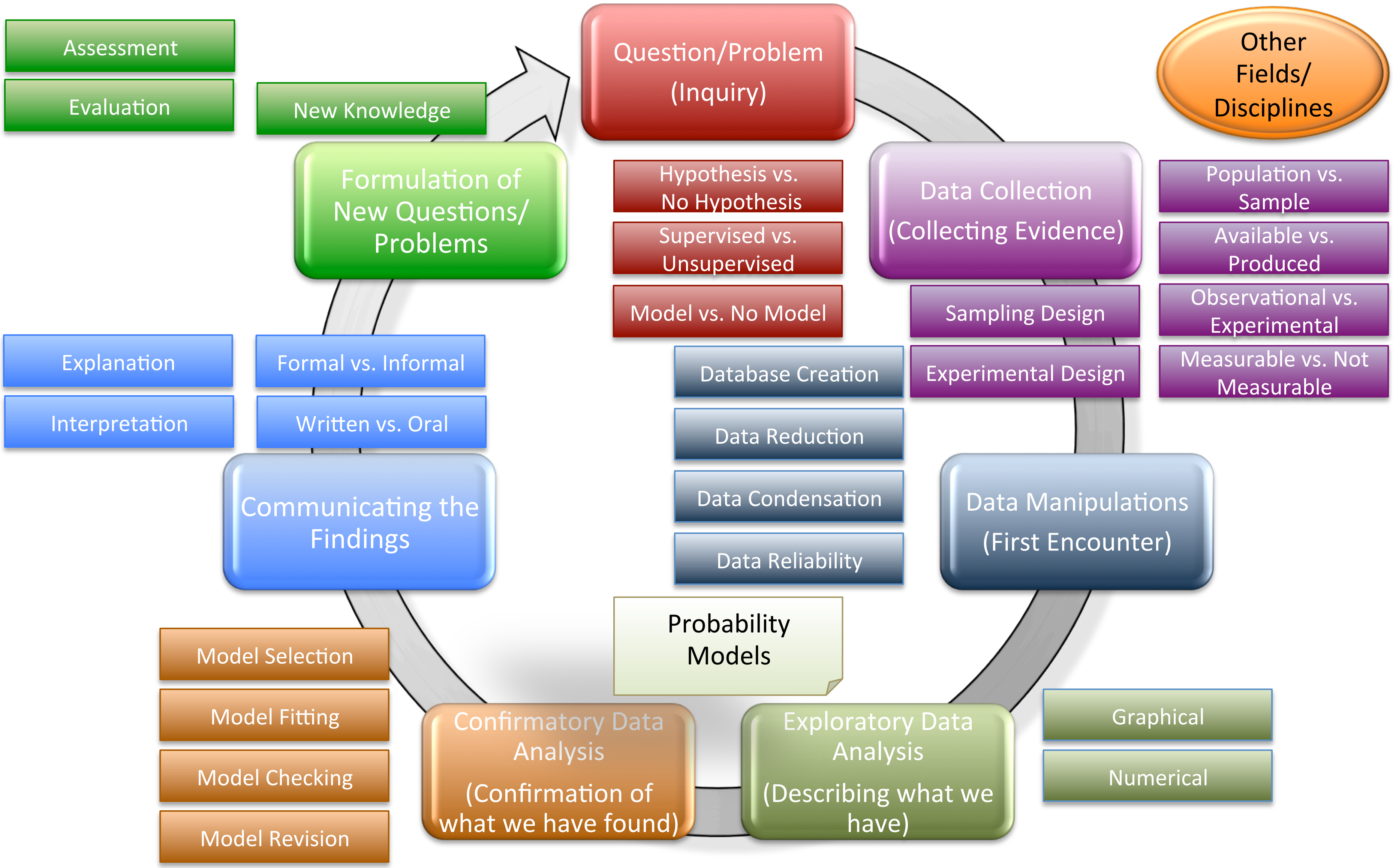
- **NONPARAMETRIC/DISTRIBUTION FREE TECHNIQUES**

http://mnstats.morris.umn.edu/introstat/nonparametric/learningtools.html

# COMMUNICATING THE FINDINGS



# FORMULATING NEW QUESTIONS/PROBLEMS



# CONCLUDING REMARKS

- SEE ME FOR A HELP

- QUESTIONS?

- IF NOT, I HAVE SOME FOR YOU. PLEASE TAKE THE TEST BEFORE YOU LEAVE