

Guide for Annotating Gold Explanations with Relations for Elementary Science Exams

Peter Jansen

Last Updated October 26th, 2016

Contents

1	Introduction	2
2	Paper/Citation	2
3	Example Explanations	2
4	Generating Explanations: 8 Principles	3
5	Statements: Consistency, living document, comments, questions, additions, changelog	4
6	Annotating Explanation Sentences with Relations	5
6.1	GUI Annotation Tool	6
6.2	Annotation Guide: Retrieval Type Annotation	7
6.2.1	Taxonomic	7
6.2.2	Definition	8
6.2.3	Properties	10
6.2.4	PartOf	12
6.2.5	Contains	13
6.2.6	ExampleOf	14
6.2.7	MadeOf	15
6.3	Annotation Guide: Inference-Supporting Type Annotation	16
6.3.1	Actions	17
6.3.2	UsedFor	18
6.3.3	Source	20
6.3.4	IsWhen	22
6.3.5	VehicleFor	23
6.3.6	Requires	24
6.3.7	Negation	25
6.3.8	Duration	26
6.4	Annotation Guide: Complex Inference Type Annotation	27
6.4.1	Changes	28
6.4.2	Causes	30
6.4.3	Transfer	31
6.4.4	IfThen	33
6.4.5	Relationship	35
6.4.6	Process Relations	37
6.5	Annotation Guide: Quantifiers/Scope	40
6.5.1	Quantifier/Scope	40

1 Introduction

This is a quick reference for generating and annotating gold explanations in the context of explainable inference for elementary science exams.

2 Paper/Citation

This guide couples with the paper “*What’s in an Explanation? Characterizing Knowledge and Inference Requirements for Elementary Science Exams*” by Peter Jansen, Niranjan Balasubramanian, Mihai Surdeanu, and Peter Clark (COLING 2016).

3 Example Explanations

From the COLING 2016 paper:

<i>Question</i>	Which of these organisms has cells with cell walls?
<i>Answer Choices</i>	(A) bluebird (B) A pine tree (C) A ladybug (D) A fox squirrel
<i>Explanation</i>	A pine tree is a kind of plant. A cell wall is a part of a plant cell.
<i>Question</i>	What form of energy causes an ice cube to melt?
<i>Answer Choices</i>	(A) mechanical (B) magnetic (C) sound (D) heat
<i>Explanation</i>	An ice cube is a solid. Changing from a solid to a liquid is called melting. Melting happens when solids are heated. Heated means added heat. Heat is a kind of energy.
<i>Question</i>	Which of the following events involves a consumer and producer in a food chain?
<i>Answer Choices</i>	(A) A cat eats a mouse. (B) A deer eats a leaf. (C) A hawk eats a mouse. (D) A snake eats a rat.
<i>Explanation</i>	A leaf is a kind of plant. A deer is a kind of animal. In a food chain, an animal is a consumer. In a food chain, green plants are producers.

Table 1: Explanations for three shorter example questions, including one simpler question about the property of an object (having cell walls), an explicitly causal question (melting), and one question about the role of two entities in a process or model (the food chain). Dashed underlines indicate bridge sentences.

4 Generating Explanations: 8 Principles

The explanations are generally generated with the goal of automatically analyzing the knowledge that they contain. We do this both to characterize the knowledge requirements for elementary science exams, and using these explanations to inform the processes by which we perform inference.

1. **Grade-appropriate Language:** Use simple, grade-appropriate language. The words used in an explanation should be known by an elementary science student studying for their test, and where possible, drawn from the language of the question itself, or elementary science textbooks or study guides.
2. **Simple Sentences:** Break the explanation into multiple sentences, with each sentence having as close to a single fact as possible. This greatly simplifies the relation annotation process.
3. **Reuse Sentences:** Where possible, reuse (exactly) sentences from explanations that have already been generated. This simplifies overlap analysis, and reduces the number of explanation sentences to annotate.
4. **Consistent Language:** Try to reuse the same terminology within and across sentences, when referring to the same thing.
5. **Knowledge Resources:** When possible, try to draw sentences directly from grade-appropriate knowledge resources, like study guides, science dictionaries for kids, the simple wiktionary, etc. If you can not find a sentence that exactly matches the need, modify one you do find, or construct a new sentence in a similar style. Simplify and/or split as required (see Principle 2).
6. **Bridge Sentences:** To support automated inference, the terminology used in different explanation sentences should be explicitly linked through “bridge sentences” that include both terms. For example, if one sentence mentions *melting*, and another mentions *heated*, here we need to author an explicit sentence that links the two, such as “*melting happens when solids are heated*”.
7. **World/Implicit Knowledge:** World knowledge that is implicitly available to humans but not known by machines also must be included. For example, “*a pine tree is a kind of plant*”.
8. **Completeness:** An overarching theme of 6 and 7 is completeness – including enough knowledge that the explanation is a solid description of the inference required for a human to arrive at the correct answer.

5 Statements: Consistency, living document, comments, questions, additions, changelog

A Note on Annotation consistency: As noted by Clark et al. (AKBC 2013), “*A study of the Knowledge Base Requirements for Passing an Elementary Science Test*”, annotating knowledge and inference requirements for questions is often a challenging task. While some questions instantiate clear-cut cases of a requiring a particular knowledge or inference method to solve, many other questions may appear to be in a grey area that requires interpreting the spirit of the task, and having the annotator make their best judgement call.

This COLING 2016 procedure attempts to mitigate some of these difficulties by developing natural language explanations for why a given answer is correct, forcing the annotator to make an explicit record of the inference required to solve a question, then annotate that explanation for common kinds of knowledge and inference relations.

This addition of explanations to the procedure can add substantial annotation time to the task, but appears to greatly reduce the number of “grey areas” in the annotation process where the annotator is required to make their best judgement call – but it does not eliminate them. Clearly rather than being the final word in annotating knowledge and inference requirements, instead it is our hope that the COLING 2016 procedure is a next significant step in further defining, specifying, and analyzing this task. As such, while a great deal of effort has been made to keep the annotation consistent, there are undoubtedly typos and consistency issues that have slipped through the cracks. Please consider reporting issues and suggesting **diffs** to the contact below.

Comments, questions, additions: This document is maintained by Peter Jansen (pajansen@email.arizona.edu). Please feel free to get in touch with comments or questions.

Living Document: This is a living knowledge resource and document, and we hope to add additional gold explanations and relation annotation for those explanations as they become available.

Changelog/Revisions:

Date	Notes
October 2016	Initial release. Gold explanations for training portion of elementary dataset (432 questions), with relation annotation for 50% of those questions.

Table 2: Changelog.

6 Annotating Explanation Sentences with Relations

We annotate each sentence in an explanation with an *n-ary relation* that describes the knowledge present in that sentence. These relations are developed in the COLING 2016 paper, and are found in Table 3. This small relation vocabulary was developed in a “goldilocks zone” of specificity, where the relations are not so high-level that they provide little information, while also not being too low-level that they would be specific and only applicable to science exams.

Knowledge Type	Prop.	Structure and Examples
<i>Retrieval Types</i>		
Taxonomic	83%	<i>HYPONYM</i> is a kind of <i>HYPERNYM</i> a < <i>HYPON</i> : plant> is a kind of < <i>HYPER</i> : living thing>
Definition	64%	<i>ARG1</i> means <i>ARG2</i> (can be definitions or synonyms) < <i>ARG1</i> : cooling> means < <i>ARG2</i> : decreasing heat> (definition)
Properties	41%	<i>PROPERTY</i> is a property of <i>ARG1</i> < <i>ARG1</i> : iron> is < <i>PROP</i> : magnetic>
PartOf	22%	<i>MERONYM</i> is a part of <i>HOLONYM</i> . a < <i>HOLON</i> : bicycle> has < <i>MERON</i> : two pedals>.
Contains	17%	<i>ARG1</i> contains <i>ARG2</i> . < <i>ARG1</i> : soil> contains < <i>ARG2</i> : nutrients> that plants absorb through their roots
ExampleOf	9%	<i>ARG1</i> is an example of <i>ARG2</i> an example of a < <i>ARG1</i> : seasonal change> is < <i>ARG2</i> : growing thick fur>
MadeOf	8%	<i>ARG1</i> is made of <i>ARG2</i> . a < <i>ARG1</i> : rock> is a hard substance composed of < <i>ARG2</i> : minerals>
<i>Inference Supporting Types</i>		
Actions	73%	<i>SUBJECT ACTION OBJECT</i> < <i>SUBJ</i> : bees> < <i>ACTION</i> : eat> < <i>OBJ</i> : pollen>
UsedFor	33%	<i>WHO</i> uses <i>WHAT</i> , and <i>WHY</i> . < <i>WHO</i> : squirrels> < <i>WHAT</i> : store food in the autumn> < <i>WHY</i> : to eat over the winter>
Source	23%	<i>WHO</i> generates/is a source of <i>WHAT</i> , and <i>HOW</i> . natural gas is can be burned in power stations to make electricity (note sourceof+generate)
IsWhen	22%	<i>ARG1</i> is when <i>ARG2</i> happens. (often used for defining events/processes) < <i>ARG1</i> : mechanical weathering> is when < <i>ARG2</i> : rocks are broken down by mechanical ...>
VehicleFor	17%	<i>WHAT</i> happens by/through some means or <i>VEHICLE</i> when < <i>WHAT</i> : pollen is carried from flower to flower> < <i>VEHICLE</i> : by pollinating animals>
Requires	12%	<i>WHO</i> requires <i>WHAT</i> , and <i>WHY</i> . < <i>WHO</i> : animals> need to < <i>WHAT</i> : eat food> < <i>WHY</i> : to get nutrients required for survival>
Negation	12%	<i>ARG1</i> is not <i>ARG2</i> . aluminum is not < <i>NOT</i> : magnetic>
Duration	10%	<i>ARG1</i> has some <i>DURATION</i> many birds < <i>ARG1</i> : migrate to warmer places> < <i>DUR</i> : for the winter>
<i>Complex Inference Types</i>		
Changes	45%	<i>WHO/LABEL</i> changes <i>WHAT</i> , <i>FROM</i> something <i>INTO</i> something else. < <i>LABEL</i> : boiling> means changing from a < <i>FROM</i> : solid> to a < <i>INTO</i> : liquid>
Causes	21%	<i>ARG1</i> causes <i>ARG2</i> . < <i>ARG1</i> : friction> causes < <i>ARG2</i> : the temperature of an object to increase>
Transfer	21%	<i>WHAT</i> gets transfered from a <i>SOURCE</i> to <i>DESTINATION</i> , and <i>HOW</i> this happens. ... breaks down food into < <i>WHAT</i> : nutrients> that can be < <i>HOW</i> : absorbed> by < <i>DEST</i> : the body>
IfThen	14%	<i>IF</i> a condition occurs, <i>THEN</i> a result happens. if < <i>IF</i> : something is on fire>, < <i>THEN</i> : it burns>
Relationship	12%	As <i>EVENT1</i> happens, <i>EVENT2</i> will also happen. < <i>EVENT1</i> : A decrease in the amount of water> will cause < <i>EVENT2</i> : a decrease in plant populations>
Process	8%	A group of relations, e.g. A <i>PROCESS STAGE</i> takes some <i>ACTION</i> causing a <i>RESULT</i> . as an < <i>STAGE</i> : adult bird>, < <i>ACTION</i> : it will reproduce>, < <i>RESULT</i> :starting the life cycle...>

Table 3: Fine-grained knowledge types, and the proportion of explanations that include at least one instance of a given type. Types are *n-ary* relations, containing between two and five arguments each. Note that a given example sentence often includes more than one relation, as in the case of “cooling means decreasing heat”, which includes both a *Definition* relation (i.e. means), and a *Change* relation (i.e. decreasing heat).

6.1 GUI Annotation Tool

Performing the explanation sentence relation annotation is greatly simplified using the graphical annotation tool, shown in Figure 1. The tool is implemented in Python, and is cross-platform.

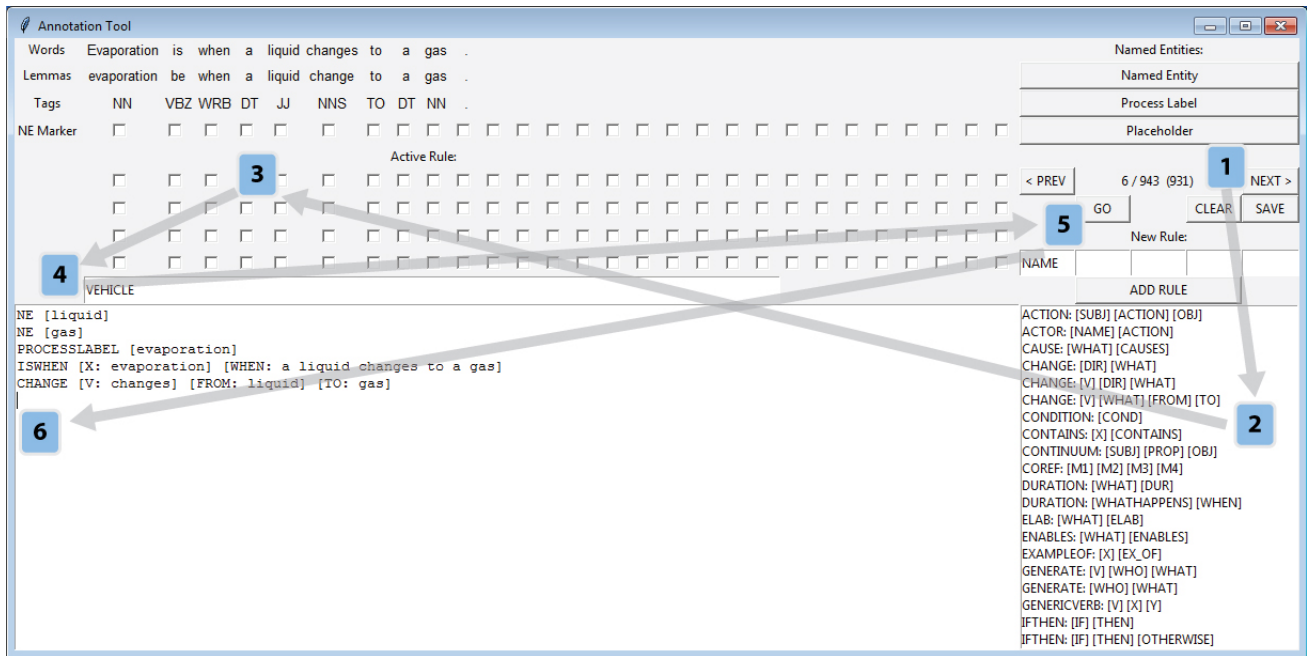


Figure 1: The graphical annotation tool.

The basic workflow of the tool is described in 6 steps:

1. **Select Sentence:** Using the next/prev buttons (or the arrow keys), the user can select the sentence they would like to annotate. The words, lemmas, and part-of-speech tags for the explanation sentence are shown in the *top left*.
2. **Select Relation:** Using the scrollbox in the *bottom right*, select the *n-ary relation* that you would like to add to the annotation for this sentence.
3. **Select Words in Arguments:** Using the array of checkboxes along the top of the screen, select which words you would like to assign to each of the (up to 4) arguments in the question.
4. **Verify Relation Annotation:** The annotation for the current relation will progressively build in the text box directly below the array of checkboxes. After Step 3 (above) is complete, verify the annotation is correct here.
5. **Add annotation:** Once the annotation for this relation has been verified correct, click the “GO” button.
6. **Annotation Added:** The new relation should now be added to the large text box on the *bottom left*, which shows the current annotation for this question. The example figure shows that annotation has already been added for 2 relations: an **ISWHEN** definitional relation, and a **CHANGE** relation.

Other notes:

- The tool also includes buttons to quickly mark whether a word is a named entity, name of a process, or a placeholder term that requires coreference resolution (e.g. something, it). This operates as above, but no rule is required to be selected – simply select the words of interest using the uppermost array of checkboxes, then click the appropriate button.
- It is recommended that you **save often**.

6.2 Annotation Guide: Retrieval Type Annotation

The *retrieval-type* knowledge category refers to knowledge that is likely to be found in taxonomies, property databases, dictionaries, and similar knowledge resources. These are often binary relations (i.e. 2 arguments).

6.2.1 Taxonomic

Purpose: Taxonomic relations define hierarchical category membership (e.g. X is a kind of Y).

Specific forms and usages: There is only a single form for this relation.

1. KINDOF [X] [KINDOF]

ARG X: The subordinate member

ARG KINDOF: The superordinate category

Examples:

1. **Easy:** A plant is a kind of organism

KINDOF [X: plant] [KINDOF: organism]

2. **Easy:** Hiding is a form of protection from predators

KINDOF [X: Hiding] [KINDOF: protection]

QUANT [WHAT: protection] [COND: from predators]

3. **Moderate:** A stove is a kind of machine used to generate heat, usually for cooking.

KINDOF [X: stove] [KINDOF: machine]

QUANT [QUANT: usually] [COND: cooking]

USEDFOR [WHAT: heat] [FOR: cooking]

SOURCEOF [WHAT: stove] [HOW: generate] [SOURCEOF: heat]

6.2.2 Definition

Purpose: Definition relations describe either synonymy or definitional knowledge (e.g. heating means adding heat, changing from a solid to a liquid is called melting).

Specific forms and usages: There are two related forms for this relation.

1. ISCALLED [WHAT] [ISCALLED]

ARG WHAT: The definition/description of the thing

ARG ISCALLED: What that thing is called

2. MEANS [X] [MEANS]

ARG X: One half of the synonymy relation

ARG MEANS: The other half of the synonymy relation (i.e. what it is equivalent to)

Special Notes: Consistency is important. Currently, explicit lexical cues in the explanation sentence (e.g. observing the word “*means*” or “*is called*”) is often what it used to decide between using the **ISCALLED** or **MEANS** relation. In practice, **ISCALLED** relations are almost always definitional relations, where as **MEANS** relations are a catch-all for many kinds of definition relations, including synonymy. Currently we group these all under the umbrella of “definition relations”, but may wish to refine this to subcategories and recomplete the annotation at some point in the future.

Examples (ISCALLED):

1. **Easy:** Changing from a solid to a liquid is called melting.

CHANGE [V: changing] [FROM: solid] [TO: liquid]

ISCALLED [WHAT: changing from a solid to a liquid] [ISCALLED: melting]

2. **Easy:** A bird that has just hatched is called a hatchling.

QUANT [WHAT: hatched] [QUANT: just]

ISCALLED [WHAT: bird that has just hatched] [ISCALLED: hatchling]

ACTION [SUBJ: bird] [ACTION: hatched]

3. **Easy:** Plants reproduce through a process called pollination.

ACTION [SUBJ: Plants] [ACTION: reproduce]

ISCALLED [WHAT: Plants reproduce] [ISCALLED: pollination]

KINDOF [X: pollination] [KINDOF: process]

4. **Moderate:** Sound is heard through a sense called hearing.

ACTION [SUBJ: Sound] [ACTION: heard]

VEHICLE [WHAT: Sound is heard] [BYTHROUGH: sense called hearing]

ISCALLED [WHAT: sense] [ISCALLED: hearing]

Examples (MEANS):

1. **Easy:** Break down means to change a whole into pieces.

CHANGE [V: change] [FROM: a whole] [TO: pieces]
MEANS [X: Break down] [MEANS: change a whole into pieces]

2. **Easy:** Heating means adding heat.

MEANS [X: Heating] [MEANS: adding heat]
CHANGE [DIR: adding] [WHAT: heat]

3. **Easy:** Protecting something means preventing harm.

ACTION [ACTION: Protecting] [OBJ: something]
ACTION [ACTION: preventing] [OBJ: harm]
MEANS [X: Protecting something] [MEANS: preventing harm]

4. **Easy:** CO2 means Carbon Dioxide.

MEANS [X: CO2] [MEANS: Carbon Dioxide]

5. **Moderate:** Natural resources are things that come from nature.

COREF [M1: Natural resources] [M2: things]
QUANT [WHAT: resources] [COND: Natural]
SOURCEOF [WHAT: nature] [HOW: come from] [SOURCEOF: things]
MEANS [X: Natural resources] [MEANS: things that come from nature]

6. **Moderate:** A piece is a smaller part of a whole something .

QUANT [WHAT: something] [COND: whole]
QUANT [WHAT: part] [QUANT: smaller]
PARTOF [X: smaller part] [PARTOF: whole something]
MEANS [X: piece] [MEANS: smaller part of a whole something]

Note that the above example could be more appropriately annotated as an:
ISCALLED [WHAT: a smaller part of a whole something] [ISCALLED: a piece],
and the somewhat loose nature of the current definition annotation.

6.2.3 Properties

Purpose: Property relations describe common properties of objects, like color, size, shape, weight, etc. Additional curriculum-specific items may also be grouped into this category, such as whether a thing is a renewable/nonrenewable resource.

Specific forms and usages: There is only a single form for this relation.

1. PROP [X] [PROP]

ARG X: The thing

ARG PROP: The property that it has

Revision 1 TODO: The PROP relation currently only specifies the **presence** of a property dimension, but does not specify its value. To specify a value, the QUANT relation is used in conjunction with the property relation. In the future, we will annotate with a single PROP relation of the form: PROP [WHAT] [PROP] [VALUE].

Revision 1 TODO: The PROPERTY relation can be challenging for new annotators since there sometimes may be few explicit lexical cues, and determining whether something is a property or not may largely be due to historical convention (e.g. Collins and Quillian's semantic networks), and curriculum knowledge. We should develop a large set of examples to illustrate this.

Examples:

1. **Moderate:** An animal 's color is usually the color of their fur or skin.

LISTOR [W: fur] [X: skin]

COREF [M1: animal 's] [M2: their]

PARTOF [X: fur or skin] [PARTOF: their]

PROPERTY [WHAT: fur or skin] [PROP: color]

PROPERTY [WHAT: animal 's] [PROP: color]

QUANT [WHAT: color of their fur or skin] [QUANT: usually]

MEANS [X: animal 's color] [MEANS: the color of their fur or skin]

2. **Moderate:** The arctic environment is white.

PROPERTY [WHAT: arctic environment] [PROP: white]

3. **Moderate:** Eye color is an inherited characteristic.

KINDOF [X: Eye color] [KINDOF: inherited characteristic]

QUANT [WHAT: characteristic] [COND: inherited]

PROPERTY [WHAT: Eye] [PROP: color]

4. **Moderate:** Changes in season are caused by changes in the Earth 's tilt on its axis.

QUANT [WHAT: tilt] [COND: on its axis]

COREF [M1: Earth 's] [M2: its]

CHANGE [V: Changes] [WHAT: season]

CHANGE [V: changes] [WHAT: Earth 's tilt on its axis]

PROPERTY [WHAT: Earth 's] [PROP: tilt]

RELATIONSHIP [COND: changes in the Earth 's tilt on its axis] [RESULT: Changes in season]

5. **Moderate:** A bird is a kind of animal that flies .

KINDOF [X: bird] [KINDOF: animal]

PROPERTY [WHAT: bird] [PROP: flies]

Revision 1 TODO: Refine description of PROPERTY relation after collecting student annotator's feedback, and identifying difficulties.

6.2.4 PartOf

Purpose: PartOf relations define part/whole relationships (e.g. X is a part of Y).

Specific forms and usages: There is only a single form for this relation.

1. PARTOF [X] [PARTOF]

ARG X: The piece/part/component

ARG PARTOF: The whole

Examples:

1. **Easy:** The lungs are a part of the body

PARTOF [X: lungs] [PARTOF: body]

2. **Easy:** Eyes are a part of the head used to see

PARTOF [X: Eyes] [PARTOF: head]

USEDFOR [WHAT: Eyes] [FOR: to see]

3. **Moderate:** An animal 's color is usually the color of their fur or skin

LISTOR [W: fur] [X: skin]

COREF [M1: animal 's] [M2: their]

PARTOF [X: fur or skin] [PARTOF: their]

PROPERTY [WHAT: fur or skin] [PROP: color]

PROPERTY [WHAT: animal 's] [PROP: color]

QUANT [WHAT: color of their fur or skin] [QUANT: usually]

MEANS [X: animal 's color] [MEANS: the color of their fur or skin]

6.2.5 Contains

Purpose: Contains relations abstract or concrete containment relationships (e.g. X contains Y, X is in Y).

Specific forms and usages: There is only a single form for this relation.

1. CONTAINS [X] [CONTAINS]

ARG X: The container

ARG CONTAINS: The thing being contained or inside the container

Examples:

1. **Easy:** Soil contains nutrients that plants absorb through their roots

ACTION [SUBJ: plants] [ACTION: absorb]

VEHICLE [WHAT: plants absorb] [BYTHROUGH: through their roots]

CONTAINS [X: Soil] [CONTAINS: nutrients]

QUANT [WHAT: nutrients] [COND: that plants absorb through their roots]

2. **Easy:** New York State is in the United States of America .

CONTAINS [X: United States of America] [CONTAINS: New York State]

3. **Moderate:** Soil with a lot of nutrients is high quality soil

IFTHEN [IF: Soil with a lot of nutrients] [THEN: high quality soil]

CONTAINS [X: Soil] [CONTAINS: a lot of nutrients]

6.2.6 ExampleOf

Purpose: ExampleOf relations list specific examples of something (e.g. X, such as Y and Z).

Specific forms and usages: There is only a single form for this relation.

1. **EXAMPLEOF** [X] [EX_OF]
 ARG X: The instance
 ARG EX_OF: The class

Examples:

1. **Easy:** Storing something to use later is an example of preparing for something

USEDFOR [WHAT: Storing something] [FOR: use later]
ACTION [ACTION: Storing] [OBJ: something]
QUANT [WHAT: preparing] [COND: for something]
EXAMPLEOF [X: Storing something to use later] [EX_OF: preparing for something]
QUANT [WHAT: use] [COND: later]

2. **Easy:** An example of migration is moving to a warmer climate in the winter to avoid cold months .

QUANT [WHAT: moving to a warmer climate] [COND: in the winter]
PURPOSE [X: moving to a warmer climate in the winter] [WHY: to avoid]
EXAMPLEOF [X: moving to a warmer climate ... to avoid cold months] [EX_OF: migration]
DURATION [WHAT: moving to a warmer climate] [DUR: in the winter]
ACTION [ACTION: avoid] [OBJ: cold months]
QUANT [WHAT: months] [COND: cold]
TRANSFER [HOW: moving] [DEST: a warmer climate]
PURPOSE [X: moving to a warmer climate in the winter] [WHY: to avoid cold months]

3. **Moderate:** Sediment is matter that falls to the bottom of bodies of water (such as oceans and lakes) .

LISTAND [W: oceans] [X: lakes]
EXAMPLEOF [X: oceans and lakes] [EX_OF: bodies of water]
KINDOF [X: Sediment] [KINDOF: matter]
ACTION [SUBJ: Sediment] [ACTION: falls] [OBJ: to the bottom]
QUANT [WHAT: bottom] [QUANT: to the] [COND: of bodies of water]
CHANGE [DIR: to the bottom] [WHAT: falls]

4. **Moderate:** Mechanical weathering is when rocks are broken down by mechanical means , including moving wind , water , or ice

LISTOR [W: wind] [X: water] [Y: ice]
QUANT [WHAT: weathering] [COND: Mechanical]
QUANT [WHAT: wind , water , or ice] [COND: moving]
EXAMPLEOF [X: moving wind , water , or ice] [EX_OF: mechanical means]
QUANT [WHAT: means] [COND: mechanical]
CHANGE [V: broken down] [WHAT: rocks]
ACTOR [NAME: mechanical means] [ACTION: rocks are broken down]
ISWHEN [X: Mechanical weathering] [WHEN: rocks are broken down by mechanical means]

6.2.7 MadeOf

Purpose: MadeOf relations describe what something is made out of (e.g. X is made of Y).

Specific forms and usages: There is only a single form for this relation.

1. MADEOF [X] [MADEOF]
ARG X: The thing
ARG MADEOF: What that thing is made out of

Examples:

1. **Easy:** A metal fork is made out of metal

MADEOF [X: fork] [MADEOF: metal]
QUANT [WHAT: fork] [COND: metal]

2. **Moderate:** Sediment is the basis for creating sedimentary rocks

QUANT [WHAT: rocks] [COND: sedimentary]
SOURCEOF [WHAT: Sediment] [HOW: creating] [SOURCEOF: sedimentary rocks]
MADEOF [X: sedimentary rocks] [MADEOF: Sediment]

3. **Moderate:** Sandpaper is made from sand glued to the surface of paper

KINDOF [X: sand dune] [KINDOF: hill]
MADEOF [X: hill] [MADEOF: sand]
QUANT [WHAT: hill of sand] [COND: that was piled by the wind]
VEHICLE [WHAT: piled] [BYTHROUGH: wind]

4. **Moderate:** A sand dune is a hill of sand that was piled by the wind

ACTION [SUBJ: sand] [ACTION: glued] [OBJ: surface of paper]
QUANT [WHAT: surface] [COND: of paper]
MADEOF [X: Sandpaper] [MADEOF: sand glued to the surface of paper]

6.3 Annotation Guide: Inference-Supporting Type Annotation

The *Inference-supporting type* knowledge category tends to ground knowledge in the complex inference relations. This includes describing the vehicle that enables something to happen, it's purpose, it's needs, and specific actions that it can take. Complex inference relations may have up to 4 argument slots, though it is often the case that not all are populated in a given instance.

6.3.1 Actions

Purpose: Action relations describe generic subject-verb-object tuples (e.g. X did Y to Z) that are not covered by an existing relation. Often times only two of the three parameters are specified (e.g. X did Y).

Specific forms and usages: There is only a single form for this relation.

1. ACTION [SUBJ] [ACTION] [OBJ]

ARG SUBJ: The subject of the action (i.e. who is doing the verbing)

ARG ACTION: The action verb (i.e. what is happening)

ARG OBJ: The object of the action (i.e. what receives the action)

Examples:

1. **Easy:** Metals conduct electricity .

ACTION [SUBJ: Metals] [ACTION: conduct] [OBJ: electricity]

2. **Moderate:** Daylight is the length of time that the sun shines on a location .

QUANT [WHAT: shines] [COND: on a location]

ACTION [SUBJ: sun] [ACTION: shines]

QUANT [WHAT: time] [QUANT: length]

QUANT [WHAT: sun shines] [COND: length of time]

MEANS [X: Daylight] [MEANS: length of time that the sun shines on a location]

3. **Moderate:** Motion is when an object moves in a direction .

ISWHEN [X: motion] [WHEN: an object moves in a direction]

ACTION [SUBJ: object] [ACTION: moves]

QUANT [WHAT: moves] [COND: in a direction]

TRANSFER [WHAT: object] [HOW: moves] [DEST: direction]

Note (above): Currently prepositional phrases (*e.g. in a direction*) are broken out with the QUANT relation. See the QUANT relation reference for more information.

4. **Moderate:** (Abstract) Being the source of something means emitting that thing .

COREF [M1: something] [M2: that thing]

SOURCEOF [SOURCEOF: something]

ACTION [ACTION: emitting] [OBJ: that thing]

MEANS [X: Being the source of something] [MEANS: emitting that thing]

5. **Complex:** (Abstract) The closer something is that emits light , the brighter it will appear .

COREF [M1: something] [M2: it]

ACTION [ACTION: emits] [OBJ: light]

ACTION [SUBJ: it] [ACTION: appear]

CHANGE [DIR: brighter] [WHAT: appear]

CHANGE [DIR: closer] [WHAT: something]

QUANT [WHAT: closer something is] [COND: that emits light]

RELATIONSHIP [COND: closer something is that emits light] [RESULT: brighter it will appear]

6.3.2 UsedFor

Purpose: UsedFor relations describe how or why something is used (e.g. X is used for Y).

Specific forms and usages: There are two related forms for this relation.

1. USEDFOR [WHAT] [WHO] [FOR]
 ARG WHAT: What is being used
 ARG WHO: Who is doing the using
 ARG FOR: What the thing is being used for
2. PURPOSE [X] [WHY]
 ARG X: An action
 ARG WHY: The purpose of that action

Examples:

1. **Easy: A tape measure is a tool used to measure length**

ACTION [ACTION: measure] [OBJ: length]
KINDOF [X: tape measure] [KINDOF: tool]
USEDFOR [WHAT: tape measure] [FOR: measure length]

2. **Easy: A predator is an animal that eats other animals for food**

KINDOF [X: predator] [KINDOF: animal]
USEDFOR [WHAT: eats other animals] [WHO: predator] [FOR: food]
ACTION [SUBJ: predator] [ACTION: eats] [OBJ: other animals]

3. **Easy: Animals eat food to get nutrients**

USEDFOR [WHAT: eat food] [WHO: Animals] [FOR: to get nutrients]
TRANSFER [WHAT: nutrients] [HOW: eat] [SOURCE: food] [DEST: Animals]
SOURCEOF [X: food] [SOURCEOF: nutrients]
ACTION [SUBJ: Animals] [ACTION: eat] [OBJ: food]

4. **Easy: Some animals grow thicker fur in the winter to stay warm**

QUANT [WHAT: animals] [QUANT: Some]
QUANT [WHAT: fur] [COND: thicker]
ACTION [SUBJ: Some animals] [ACTION: grow] [OBJ: thicker fur]
DURATION [WHAT: thicker fur] [DUR: in the winter]
PURPOSE [X: Some animals grow thicker fur in the winter] [WHY: to stay warm]
ACTION [ACTION: stay] [OBJ: warm]

5. **Moderate: Pedalling a bicycle involves moving the pedals in a circular motion to move the bicycle forward**

TRANSFER [WHAT: bicycle] [HOW: move] [DEST: forward]
QUANT [WHAT: motion] [COND: circular]
QUANT [WHAT: moving the pedals] [COND: in a circular motion]
PURPOSE [X: moving the pedals in a circular motion] [WHY: to move the bicycle forward]
ACTION [ACTION: moving] [OBJ: pedals]
ACTION [ACTION: Pedalling] [OBJ: bicycle]
MEANS [X: Pedalling a bicycle] [MEANS: moving the pedals in a circular motion to move the bicycle forward]

6. **Moderate: An example of migration is moving to a warmer climate in the winter to avoid cold months**

QUANT [WHAT: moving to a warmer climate] [COND: in the winter]
EXAMPLEOF [X: moving to a warmer climate in the winter to avoid cold months] [EX_OF: migration]
DURATION [WHAT: moving to a warmer climate] [DUR: in the winter]
ACTION [ACTION: avoid] [OBJ: cold months]
QUANT [WHAT: months] [COND: cold]
TRANSFER [HOW: moving] [DEST: a warmer climate]
PURPOSE [X: moving to a warmer climate in the winter] [WHY: to avoid cold months]

7. **Moderate: The petals of a flower are often brightly coloured and scented to attract pollinators**

LISTAND [W: brightly coloured] [X: scented]
PROPERTY [WHAT: petals of a flower] [PROP: brightly coloured and scented]
USEDFOR [WHAT: petals of a flower] [FOR: attract pollinators]

8. **Moderate: Shivering is shaking that creates heat to keep the body warm**

KINDOF [X: Shivering] [KINDOF: shaking]
USEDFOR [WHAT: heat] [FOR: keep the body warm]
CHANGE [V: keep] [WHAT: body] [TO: warm]
GENERATE [V: creates] [WHO: Shivering] [WHAT: heat]

6.3.3 Source

Purpose: Source relations describe where something comes from, or how it is made (e.g. X is the source of Y).

Specific forms and usages: There are two related forms for this relation.

1. SOURCEOF [WHAT] [HOW] [SOURCEOF
ARG WHAT: The thing that is the source
ARG HOW: The manner of the sourcing
ARG SOURCEOF: What it is the source of
2. GENERATE [V] [WHO] [WHAT
ARG V: The verb describing the generation
ARG WHO: Who is doing the generation
ARG WHAT: What they are generating

Examples:

1. **Easy: A star is a source of light**

SOURCEOF [WHAT: star] [SOURCEOF: light]

2. **Easy: The source of wind and water in the weathering process is usually from weather**

QUANT [WHAT: wind and water] [COND: in the weathering process]

QUANT [WHAT: process] [COND: weathering]

QUANT [WHAT: weather] [QUANT: usually]

SOURCEOF [WHAT: weather] [SOURCEOF: wind and water in the weathering process]

PROLE [PROCESS: weathering process] [ACTOR: weather] [ROLE: source of wind and water]

3. **Easy: Text: A stove is a machine used to generate heat , usually for cooking .**

KINDOF [X: stove] [KINDOF: machine]

QUANT [QUANT: usually] [COND: cooking]

USEDFOR [WHAT: heat] [FOR: cooking]

SOURCEOF [WHAT: stove] [HOW: generate] [SOURCEOF: heat]

4. **Easy: Musical instruments make sound**

QUANT [WHAT: instruments] [COND: Musical]

GENERATE [V: make] [WHO: Musical instruments] [WHAT: sound]

5. **Easy: Wood from trees can be burned to produce heat**

QUANT [WHAT: Wood] [COND: from trees]

ACTION [SUBJ: Wood] [ACTION: burned]

GENERATE [V: produce] [WHAT: heat]

VEHICLE [WHAT: produce heat] [BYTHROUGH: burned]

6. **Easy: Shivering is shaking that creates heat to keep the body warm**

KINDOF [X: Shivering] [KINDOF: shaking]
USEDFOR [WHAT: heat] [FOR: keep the body warm]
CHANGE [V: keep] [WHAT: body] [TO: warm]
GENERATE [V: creates] [WHO: Shivering] [WHAT: heat]

7. **Moderate: Plants make food through a process called photosynthesis**

KINDOF [X: photosynthesis] [KINDOF: process]
ISCALLED [WHAT: Plants make food] [ISCALLED: photosynthesis]
SOURCEOF [WHAT: Plants] [HOW: make] [SOURCEOF: food]
PSTAGE [NAME: photosynthesis] [ACTION: Plants make food]

8. **Moderate: Photosynthesis converts sunlight into sugars that a plant cell uses as food and a source of energy**

QUANT [WHAT: energy] [COND: source of]
QUANT [WHAT: cell] [COND: plant]
SOURCEOF [WHAT: sugars] [SOURCEOF: energy]
LISTAND [W: food] [X: source of energy]
CHANGE [V: converts] [FROM: sunlight] [TO: sugars]
ACTOR [NAME: Photosynthesis] [ACTION: converts sunlight into sugars]
USEDFOR [WHAT: sugars] [WHO: plant cell] [FOR: food and a source of energy]

6.3.4 IsWhen

Purpose: IsWhen relations describe definitions centered around a condition or process (e.g. X is when Y).

Specific forms and usages: There is only a single form for this relation.

1. ISWHEN [X] [ISWHEN]
ARG X: The name
ARG ISWHEN: The condition or state

Examples:

1. **Easy: Evaporation happens when liquids are heated**

CHANGE [DIR: heated] [WHAT: liquids]
ISWHEN [X: Evaporation] [WHEN: liquids are heated]

2. **Easy: Crop rotation is where different crops are planted on a field in different years**

QUANT [WHAT: crops] [COND: different]
QUANT [WHAT: years] [COND: different]
ACTION [SUBJ: different crops] [ACTION: planted]
QUANT [WHAT: planted] [COND: on a field]
QUANT [WHAT: planted on a field] [COND: in different years]
ISWHEN [X: Crop rotation] [WHEN: different crops are planted on a field in different years]

3. **Easy: Mining is when rocks and minerals are taken from the ground**

LISTAND [W: rocks] [X: minerals]
TRANSFER [WHAT: rocks and minerals] [HOW: taken] [SOURCE: ground]
ISWHEN [X: Mining] [WHEN: rocks and minerals are taken from the ground]

4. **Easy: Migration is when animals move in an annual cycle**

QUANT [WHAT: cycle] [QUANT: annual]
QUANT [WHAT: move] [COND: in an annual cycle]
ACTION [SUBJ: animals] [ACTION: move]
ISWHEN [X: Migration] [WHEN: animals move in an annual cycle]

6.3.5 VehicleFor

Purpose: VehicleFor relations describe the vehicle by/through something happens (e.g. X happens through Y).

Specific forms and usages: There is only a single form for this relation.

1. VEHICLE [WHAT] [BYTHROUGH]
ARG WHAT: What happened/happens
ARG BYTHROUGH: How it is happening

Examples:

1. Easy: A sand dune is a hill of sand that was piled by the wind

KINDOF [X: sand dune] [KINDOF: hill]
MADEOF [X: hill] [MADEOF: sand]
QUANT [WHAT: hill of sand] [COND: that was piled by the wind]
VEHICLE [WHAT: piled] [BYTHROUGH: wind]

2. Easy: Sound is heard through a sense called hearing

ACTION [SUBJ: Sound] [ACTION: heard]
VEHICLE [WHAT: Sound is heard] [BYTHROUGH: sense called hearing]
ISCALLED [WHAT: sense] [ISCALLED: hearing]

3. Easy: Weathering is usually caused by interaction with wind or water over long periods of time

LISTOR [W: wind] [X: water]
DURATION [WHAT: interaction with wind or water] [DUR: long periods of time]
QUANT [WHAT: time] [QUANT: long periods]
ACTION [ACTION: interaction] [OBJ: with wind or water]
VEHICLE [WHAT: Weathering] [BYTHROUGH: interaction with wind or water over long periods of time]

4. Easy: A rocket engine takes in fuel and produces thrust by pushing gases out at high speed

SOURCEOF [WHAT: rocket engine] [HOW: produces] [SOURCEOF: thrust]
VEHICLE [WHAT: produces thrust] [BYTHROUGH: by pushing gases out at high speed]
CHANGE [V: pushing] [DIR: out] [WHAT: gases]
QUANT [WHAT: pushing] [COND: at high speed]
CHANGE [V: takes in] [WHAT: rocket engine] [FROM: fuel] [TO: produces thrust]
USEDFOR [WHAT: fuel] [WHO: rocket engine] [FOR: produces thrust]

6.3.6 Requires

Purpose: Requires relations describe requirements or needs (e.g. X requires Y).

Specific forms and usages: There is only a single form for this relation.

1. REQUIRE [WHO] [WHAT] [WHY]
ARG WHO: Who/what has the need
ARG WHAT: What they/it need
ARG WHY: Why they/it have the need

Examples:

1. Easy: Plants require sunlight to grow

REQUIRE [WHO: Plants] [WHAT: sunlight] [WHY: to grow]

2. Easy: Counting something visually requires that you can see it well

ACTION [SUBJ: Counting] [ACTION: something]
ACTION [SUBJ: you] [ACTION: see] [OBJ: it]
QUANT [WHAT: Counting something] [COND: visually]
QUANT [WHAT: see it] [QUANT: well]
REQUIRE [WHO: Counting something visually] [WHAT: you can see it well]

3. Easy: Animals need water to survive

REQUIRE [WHO: Animals] [WHAT: water] [WHY: to survive]

4. Easy: Plants need sunlight for photosynthesis

REQUIRE [WHO: Plants] [WHAT: sunlight] [WHY: photosynthesis]

5. Moderate: Animals eat food to get the energy they need to survive

ACTION [SUBJ: Animals] [ACTION: eat] [OBJ: food]
COREF [M1: Animals] [M2: they]
USEDFOR [WHAT: eat food] [WHO: Animals] [FOR: to get the energy they need to survive]
TRANSFER [WHAT: energy] [HOW: eat] [SOURCE: food] [DEST: Animals]
ACTION [SUBJ: Animals] [ACTION: get] [OBJ: energy]
REQUIRE [WHO: they] [WHAT: energy] [WHY: to survive]

6.3.7 Negation

Purpose: Negation is more of a flag than relation, and describes when the opposite of something is true.

Specific forms and usages: There is only a single form for this relation.

1. NEG [NEG]

ARG NEG: The thing to negate

Examples:

1. **Easy: Aluminum is not magnetic**

PROPERTY [WHAT: Aluminum] [PROP: magnetic]

NEG [NEG: magnetic]

2. **Easy: Dead means to not be alive**

MEANS [X: Dead] [MEANS: alive]

NEG [NEG: alive]

3. **Easy: Cold environments usually do not have much food for animals**

QUANT [WHAT: environments] [COND: Cold]

NEG [NEG: food]

USEDFOR [WHAT: food] [WHO: animals]

CONTAINS [X: Cold environments] [CONTAINS: not have much food for animals]

ACTION [SUBJ: Cold environments] [ACTION: have] [OBJ: food]

QUANT [WHAT: food] [QUANT: much] [COND: for animals]

4. **Moderate: Rocks other than sedimentary rocks form at high temperatures and pressures , destroying animal remains , causing no fossils to be formed .**

LISTAND [W: temperatures] [X: pressures]

QUANT [WHAT: temperatures and pressures] [QUANT: high]

QUANT [WHAT: Rocks] [COND: other than sedimentary rocks]

ACTION [SUBJ: Rocks other than sedimentary rocks] [ACTION: form]

QUANT [WHAT: form] [COND: at high temperatures and pressures]

QUANT [WHAT: remains] [COND: animal]

ACTION [ACTION: destroying] [OBJ: animal remains]

ACTION [SUBJ: fossils] [ACTION: formed]

NEG [NEG: fossils]

CAUSE [WHAT: high temperatures and pressures] [CAUSES: destroying animal remains]

IFTHEN [IF: destroying animal remains] [THEN: no fossils to be formed]

6.3.8 Duration

Purpose: Duration relations describe how long something happens (e.g. X happens in the Y season).

Specific forms and usages: There is only a single form for this relation.

1. **DURATION** [WHAT] [DUR]
ARG WHAT: What happens
ARG DUR: When it happens, or how long it happens for

Examples:

1. **Easy: Plants dying in the winter is an example of a seasonal change .**

QUANT [WHAT: change] [COND: seasonal]
ACTION [SUBJ: Plants] [ACTION: dying]
DURATION [WHAT: Plants dying] [DUR: in the winter]
EXAMPLEOF [X: Plants dying in the winter] [EX_OF: seasonal change]

2. **Easy: In the Northern Hemisphere , the summer solstice is on June 21st**

QUANT [WHAT: Hemisphere] [COND: Northern]
QUANT [WHAT: solstice] [COND: summer]
DURATION [WHAT: summer solstice] [DUR: June 21st]
QUANT [WHAT: summer solstice is on June 21st] [COND: In the Northern Hemisphere]

3. **Easy: Annual means something happens once per year**

QUANT [WHAT: year] [QUANT: once per]
ACTION [SUBJ: something] [ACTION: happens]
DURATION [WHAT: something happens] [DUR: once per year]
MEANS [X: Annual] [MEANS: something happens once per year]

4. **Easy: Animals that rely on plants for food must store enough food to last through the winter**

QUANT [WHAT: food] [COND: enough]
REQUIRE [WHO: Animals] [WHAT: plants] [WHY: for food]
DURATION [WHAT: to last] [DUR: through the winter]
ACTION [SUBJ: Animals] [ACTION: store] [OBJ: enough food]
QUANT [WHAT: store enough food] [COND: to last through the winter]
IFTHEN [IF: Animals that rely on plants for food] [THEN: store enough food to last through the winter]

5. **Easy: Weathering is usually caused by interaction with wind or water over long periods of time**

LISTOR [W: wind] [X: water]
DURATION [WHAT: interaction with wind or water] [DUR: long periods of time]
QUANT [WHAT: time] [QUANT: long periods]
ACTION [ACTION: interaction] [OBJ: with wind or water]
VEHICLE [WHAT: Weathering] [BYTHROUGH: interaction with wind ... long periods of time]

6.4 Annotation Guide: Complex Inference Type Annotation

The *Complex Inference type* knowledge category describe changes situated in particular contexts, such as causality (e.g. *X causes Y*), transfers (e.g. *X transfers from Y to Z*), and process knowledge (e.g. *Stage A follows Stage B*). Complex inference relations may have up to 4 argument slots, though it is often the case that not all are populated in a given instance.

6.4.1 Changes

Purpose: Change relations describe when something **changes from one state to another** (*a discrete change, e.g. changed from a solid to a liquid*), or when something **changes in magnitude** (*a vector change, e.g. increased in temperature*).

Specific forms and usages: There are two forms for this relation, a discrete change, and a vector change. Often only some of the arguments are populated for a given instance in text:

1. **CHANGE** [V] [WHAT] [FROM] [TO] (Discrete change)
ARG V: The change verb (often this may simply be 'changes/changed')
ARG WHAT: The thing being changed
ARG FROM: The state of the thing before the change
ARG TO: The state of the thing after the change
2. **CHANGE** [WHAT] [DIR] (Vector change)
ARG WHAT: The thing being changed
ARG DIR: The direction of change (e.g. increases/decreases)

Examples (Discrete changes):

1. **Easy:** Evaporation is when a liquid changes to a gas .

ISWHEN [X: evaporation] [WHEN: a liquid changes to a gas]
CHANGE [V: changes] [FROM: liquid] [TO: gas]

Note: Explicit lexical cues (*“changes”, “to”*)

2. **Easy:** Break down means to change a whole into pieces .

PROCESSLABEL [break down]
CHANGE [V: change] [FROM: a whole] [TO: pieces]
MEANS [X: Break down] [MEANS: change a whole into pieces]

Note: Explicit lexical cues (*“change”, “into”*).

3. **Moderate:** Weathering involves breaking down a larger object into smaller pieces .

CHANGE [V: breaking down] [FROM: larger object] [TO: smaller pieces]
QUANT [WHAT: object] [QUANT: larger]
QUANT [WHAT: pieces] [QUANT: smaller]
PSTAGE [NAME: Weathering] [ACTION: breaking down a larger object into smaller pieces]

Note: Fewer explicit lexical cues (*“into”*), non-obvious change verb *“breaking down”*, somewhat abstract subject matter

4. **Moderate:** Producers are living things that convert solar energy into food for themselves .

KINDOF [X: Producers] [KINDOF: living things]
COREF [M1: Producers] [M2: themselves]
CHANGE [V: convert] [FROM: solar energy] [TO: food]
ACTOR [NAME: Producers] [ACTION: convert solar energy into food]
USEDFOR [WHAT: food] [FOR: themselves]

5. **Moderate:** Weathering is a process that breaks down rocks and other surface materials into smaller pieces .

KINDOF [X: Weathering] [KINDOF: process]
QUANT [WHAT: pieces] [COND: smaller]
QUANT [WHAT: surface materials] [COND: other]
LISTAND [W: rocks] [X: other surface materials]
CHANGE [V: breaks down] [WHAT: rocks and other surface materials] [TO: smaller pieces]
PSTAGE [NAME: Weathering] [ACTION: process that breaks down rocks and other surface materials into smaller pieces]

Note: Longer example

6. **Moderate/Abstract (not discrete or vector):** Disguise is to change appearance to hide .

CHANGE [V: change] [WHAT: appearance]
USEDFOR [WHAT: change appearance] [FOR: hide]
MEANS [X: Disguise] [MEANS: change appearance to hide]

Note: Not discrete or vector – few arguments filled.

Examples (Vector changes):

1. **Easy:** Heating means adding heat .

MEANS [X: Heating] [MEANS: adding heat]
CHANGE [DIR: adding] [WHAT: heat]

2. **Easy:** Friction causes the temperature of an object to increase .

QUANT [WHAT: temperature] [COND: of an object]
CAUSE [WHAT: Friction] [CAUSES: temperature of an object to increase]
CHANGE [DIR: increase] [WHAT: temperature]

3. **Moderate:** The closer something is that emits light , the brighter it will appear .

COREF [M1: something] [M2: it]
ACTION [ACTION: emits] [OBJ: light]
ACTION [SUBJ: it] [ACTION: appear]
CHANGE [DIR: brighter] [WHAT: appear]
CHANGE [DIR: closer] [WHAT: something]
QUANT [WHAT: closer something is] [COND: that emits light]
RELATIONSHIP [COND: closer something is that emits light] [RESULT: brighter it will appear]

Note: Multiple **CHANGES** in one sentence

6.4.2 Causes

Purpose: Causal relations describe when one thing triggers another (e.g. X causes Y).

Specific forms and usages: There is only a single form for this relation.

1. CAUSE [WHAT] [CAUSES]

ARG WHAT: The precondition

ARG CAUSES: What the precondition causes to happen

Examples:

1. **Easy:** Friction causes the temperature of an object to increase .

QUANT [WHAT: temperature] [COND: of an object]

CAUSE [WHAT: Friction] [CAUSES: temperature of an object to increase]

CHANGE [DIR: increase] [WHAT: temperature]

Note: Explicit lexical cue (*“causes”*)

2. **Moderate:** Soil erosion is the loss of soil from water or wind .

LISTOR [W: water] [X: wind]

ISCALLED [WHAT: loss of soil from water or wind] [ISCALLED: Soil erosion]

CHANGE [DIR: loss] [WHAT: soil]

CAUSE [WHAT: water or wind] [CAUSES: loss of soil]

Note: No explicit lexical cue

3. **Moderate:** Ice wedging is a kind of mechanical weathering resulting from freezing and thawing water .

QUANT [WHAT: weathering] [COND: mechanical]

KINDOF [X: Ice wedging] [KINDOF: weathering]

LISTAND [W: freezing] [X: thawing]

ACTION [ACTION: freezing and thawing] [OBJ: water]

CAUSE [WHAT: freezing and thawing water] [CAUSES: Ice wedging]

Note: Direction of relation is (a) opposite the order in text, and (b) distant (separated by *“is a kind of mechanical weathering”*)

4. **Moderate:** A decomposer breaks down dead organisms and recycles their nutrients into the soil .

COREF [M1: organisms] [M2: their]

QUANT [WHAT: organisms] [COND: dead]

QUANT [WHAT: nutrients] [COND: their]

TRANSFER [WHAT: their nutrients] [HOW: recycles] [DEST: soil]

CHANGE [V: breaks down] [WHAT: dead organisms]

ACTOR [NAME: decomposer] [ACTION: breaks down dead organisms]

CAUSE [WHAT: decomposer breaks down dead organisms] [CAUSES: recycles their nutrients into the soil]

Note: No explicit lexical cue – one action (*break down dead organisms*) leads to the result (*recycle nutrients into the soil*).

6.4.3 Transfer

Purpose: Transfer relations describe when and how something moves from one place to another (e.g. X moves from Y to Z).

Specific forms and usages: There is only a single form for this relation.

1. TRANSFER [WHAT] [HOW] [SOURCE] [DEST]
ARG WHAT: What is being transferred
ARG HOW: The manner of the transfer
ARG SOURCE: Where the thing started before being transferred
ARG DEST: Where the thing is going/will go after being transferred

Examples:

1. **Easy:** Lava is magma that flows onto the Earth 's surface .

PARTOF [X: surface] [PARTOF: Earth 's]
TRANSFER [WHAT: magma] [HOW: flows] [DEST: Earth 's surface]
MEANS [X: Lava] [MEANS: magma that flows onto the Earth 's surface]

2. **Moderate:** A decomposer breaks down dead organisms and recycles their nutrients into the soil .

COREF [M1: organisms] [M2: their]
QUANT [WHAT: organisms] [COND: dead]
QUANT [WHAT: nutrients] [COND: their]
TRANSFER [WHAT: their nutrients] [HOW: recycles] [DEST: soil]
CHANGE [V: breaks down] [WHAT: dead organisms]
ACTOR [NAME: decomposer] [ACTION: breaks down dead organisms]
CAUSE [WHAT: decomposer breaks down dead organisms] [CAUSES: recycles their nutrients into the soil]

Note: Longer example, source not included – though arguably this one may also be annotated as **TRANSFER [WHAT: nutrients] [HOW: recycles] [SOURCE: dead organisms] [DEST: soil]**

3. **Moderate:** An inherited characteristic is a characteristic that is copied from a parent to the offspring .

KINDOF [X: inherited characteristic] [KINDOF: characteristic]
TRANSFER [WHAT: characteristic] [HOW: copied] [SOURCE: parent] [DEST: offspring]
QUANT [WHAT: characteristic] [COND: copied from a parent to the offspring]
QUANT [WHAT: characteristic] [COND: inherited]

Note: Somewhat explicit lexical cue (*“copied”*)

4. **Moderate:** Sunlight means energy from the sun .

MEANS [X: Sunlight] [MEANS: energy]
QUANT [WHAT: energy] [COND: from the sun]
TRANSFER [WHAT: energy] [SOURCE: sun]

Note: Somewhat abstract. Explicit lexical cue (*“from”*).

5. **Moderate:** Recycling reduces the amount of waste sent to landfills .

QUANT [WHAT: waste] [QUANT: amount of]
TRANSFER [WHAT: waste] [HOW: sent] [DEST: landfills]
ACTION [SUBJ: Recycling] [ACTION: reduces] [OBJ: amount of waste sent to landfills]
CHANGE [DIR: reduces] [WHAT: amount of waste sent to landfills]
ACTOR [NAME: Recycling] [ACTION: reduces the amount of waste sent to landfills]

6. **Challenging:** Motion is when an object moves in a direction .

ISWHEN [X: motion] [WHEN: an object moves in a direction]
ACTION [SUBJ: object] [ACTION: moves]
QUANT [WHAT: moves] [COND: in a direction]
TRANSFER [WHAT: object] [HOW: moves] [DEST: direction]

Note: Highly abstract. Explicit lexical cue (*“moves”*)

7. **Challenging:** Metal objects conduct heat energy .

QUANT [WHAT: energy] [COND: heat]
QUANT [WHAT: objects] [COND: Metal]
ACTION [SUBJ: Metal objects] [ACTION: conduct] [OBJ: heat energy]
TRANSFER [WHAT: heat energy] [HOW: conduct]
ACTOR [NAME: Metal] [ACTION: conduct heat energy]

Note: Abstract, no explicit source or destination

6.4.4 IfThen

Purpose: IfThen relations describe situations where something happens if a given condition is met (e.g. if X then Y).

Specific forms and usages: There is only a single form for this relation.

1. IFTHEN [IF] [THEN] [UNLESS] [OTHERWISE]

ARG IF: The condition

ARG THEN: The result

ARG UNLESS: An exception to the condition happening

ARG OTHERWISE: If the condition is not met, this happens

Examples:

1. **Easy:** If something contains a large amount of metal , then it may attract magnets .

CONTAINS [X: something] [CONTAINS: large amount of metal]
QUANT [WHAT: metal] [COND: large amount of]
COREF [M1: something] [M2: it]
ACTION [SUBJ: it] [ACTION: attract] [OBJ: magnets]
QUANT [WHAT: attract] [COND: may]
IFTHEN [IF: something contains a large amount of metal] [THEN: it may attract magnets]

Note: Explicit lexical cues (*“if”*, *“then”*)

2. **Moderate:** Soil with a lot of nutrients is high quality soil

QUANT [WHAT: nutrients] [QUANT: a lot of]
QUANT [WHAT: soil] [COND: quality]
QUANT [WHAT: quality] [QUANT: high]
COREF [M1: Soil] [M2: soil]
IFTHEN [IF: Soil with a lot of nutrients] [THEN: high quality soil]
CONTAINS [X: Soil] [CONTAINS: a lot of nutrients]

Note: Largely structural cues (X meeting condition Y is given label Z)

3. **Moderate:** When a body of water receives more water than it can hold , it floods .

COREF [M1: body of water] [M2: it] [M3: it]
ACTION [SUBJ: it] [ACTION: floods]
QUANT [WHAT: water] [QUANT: more] [COND: than it can hold]
CONDITION [COND: than it can hold]
ACTION [SUBJ: body of water] [ACTION: receives] [OBJ: more water than it can hold]
IFTHEN [IF: body of water receives more water than it can hold] [THEN: it floods]

Note: Largely structural cues (When X meets condition Y then Z happens)

4. **Moderate:** When plants grow , they may increase the size or number of their leaves .

ACTION [SUBJ: plants] [ACTION: grow]
CHANGE [DIR: increase] [WHAT: size or number]

QUANT [WHAT: size or number] [COND: of their leaves]
 LISTOR [W: size] [X: number]
IFTHEN [IF: plants grow] [THEN: may increase the size or number of their leaves]

Note: Largely structural cues (When X meets condition Y then Z happens)

5. **Moderate:** When an object is partially in water , it is also partially in air .

COREF [M1: object] [M2: it]
 QUANT [WHAT: in water] [QUANT: partially]
 QUANT [WHAT: in air] [QUANT: partially]
IFTHEN [IF: an object is partially in water] [THEN: it is also partially in air]
 PROPERTY [WHAT: object] [PROP: partially in water]
 PROPERTY [WHAT: it] [PROP: partially in air]

Note: Highly abstract

6. **Moderate:** When objects are in motion , they will eventually stop due to friction , unless force is continually added .

ACTION [SUBJ: objects] [ACTION: in motion]
 COREF [M1: objects] [M2: they]
 ACTION [SUBJ: they] [ACTION: stop]
 QUANT [WHAT: stop] [COND: eventually]
 CAUSE [WHAT: friction] [CAUSES: they will eventually stop]
 ACTION [SUBJ: force] [ACTION: added]
 QUANT [WHAT: added] [COND: continually]
IFTHEN [IF: objects are in motion] [THEN: they will eventually stop due to friction] [UNLESS: unless force is continually added]

Note: Long example, with UNLESS condition populated

6.4.5 Relationship

Purpose: Relationship relations describe a coupled relationship when something varies as a result of something else varying (e.g. X increases as Y decreases).

Specific forms and usages: There is only a single form for this relation.

1. **RELATIONSHIP** [COND] [RESULT]

ARG COND: The first half of the coupled relationship (the condition)

ARG RESULT: The second half of the coupled relationship (the result)

Note to annotators: If you find that you have two **CHANGE** relations in a sentence that have some causal relation, this is likely a **RELATIONSHIP** relation, and not a **CAUSE**.

Examples:

1. **Easy:** Friction increases as surface roughness increases .

QUANT [WHAT: roughness] [COND: surface]

CHANGE [DIR: increases] [WHAT: Friction]

CHANGE [DIR: increases] [WHAT: surface roughness]

RELATIONSHIP [COND: Friction increases] [RESULT: surface roughness increases]

Note: Two **CHANGES** separated by helpful lexical cue (*“as”*)

2. **Moderate:** The closer something is that emits light , the brighter it will appear .

COREF [M1: something] [M2: it]

ACTION [ACTION: emits] [OBJ: light]

ACTION [SUBJ: it] [ACTION: appear]

CHANGE [DIR: brighter] [WHAT: appear]

CHANGE [DIR: closer] [WHAT: something]

QUANT [WHAT: closer something is] [COND: that emits light]

RELATIONSHIP [COND: closer something is that emits light] [RESULT: brighter it will appear]

Note:

3. **Challenging:** Changes in season are caused by changes in the Earth 's tilt on its axis .

QUANT [WHAT: tilt] [COND: on its axis]

COREF [M1: Earth 's] [M2: its]

CHANGE [V: Changes] [WHAT: season]

CHANGE [V: changes] [WHAT: Earth 's tilt on its axis]

PROPERTY [WHAT: Earth 's] [PROP: tilt]

RELATIONSHIP [COND: changes in the Earth 's tilt on its axis] [RESULT: Changes in season]

Note: Challenging – lexical cues may point to a **CAUSE** relation, but the quantities on either side are both changes (e.g. **CHANGE-CAUSE-CHANGE**), which means a coupled relationship, and a **RELATIONSHIP** relation.

4. **Challenging:** If a prey population decreases , the predator population may decrease .

QUANT [WHAT: population] [COND: prey]

QUANT [WHAT: population] [COND: predator]

CHANGE [DIR: decreases] [WHAT: prey population]

CHANGE [DIR: decrease] [WHAT: predator population]

RELATIONSHIP [COND: prey population decreases] [RESULT: predator population may decrease]

Note: Also challenging – lexical cues may point to an **IFTHEN** relation, but the quantities on either side are both changes (e.g. **IF-CHANGE-THEN-CHANGE**), which means a coupled relationship, and a **RELATIONSHIP** relation.

6.4.6 Process Relations

Purpose: Process relations are a group of relations that describe the start/end of processes, the actions undertaken at a particular stage of a process, or the role of an entity during some process.

These are some of the most infrequent relations described in the COLING paper – only about 8% of explanations contain at least one of the many process relations. As such, examples of specific process representations may be underrepresented in the current dataset, but many of the forms are fairly straightforward. The underrepresentation means that these may be further refined as more examples are included in the dataset.

Specific forms and usages: There are numerous forms for this relation group.

1. **PSTART** [PROCESS] [BEGINSWITH]

ARG PROCESS: The process name (e.g. life cycle)

ARG BEGINSWITH: What it begins with (e.g. being born)

2. **PEND** [PROCESS] [ENDSWITH]

ARG PROCESS: The process name (e.g. life cycle)

ARG ENDSWITH: What it ends with (e.g. death)

3. **PSTAGE** [NAME] [ACTION] [RESULT]

ARG NAME:

ARG ACTION:

ARG RESULT:

4. **PROLE** [PROCESS] [ACTOR] [ROLE]

ARG PROCESS:

ARG ACTOR:

ARG ROLE:

5. **PLINK** [PREVACTION] [NEXTACTION]

ARG PREVACTION:

ARG NEXTACTION:

Examples (PSTART):

1. **Easy:** Soil development starts with weathering bedrock .

ACTION [ACTION: weathering] [OBJ: bedrock]

QUANT [WHAT: development] [COND: Soil]

PSTART [PROCESS: Soil development] [BEGINSWITH: weathering bedrock]

Note: Explicit lexical cue (*X starts with...*)

Examples (PEND):

1. **Moderate:** The life cycle describes stages from birth to death .

PSTART [PROCESS: life cycle] [BEGINSWITH: birth]

PEND [PROCESS: life cycle] [ENDSWITH: death]

CHANGE [WHAT: stages] [FROM: birth] [TO: death]

ACTION [SUBJ: life cycle] [ACTION: describes] [OBJ: stages from birth to death]

Note:

Examples (PSTAGE):

1. **Moderate:** An adult may reproduce , starting the life cycle over again for it 's children .

COREF [M1: adult] [M2: it 's]
QUANT [WHAT: reproduce] [QUANT: may]
ACTION [SUBJ: adult] [ACTION: reproduce]
ACTION [ACTION: starting] [OBJ: life cycle]
QUANT [WHAT: starting the life cycle] [COND: for it 's children]
PROPERTY [WHAT: it 's] [PROP: children]
**PSTAGE [NAME: life cycle] [ACTION: adult may reproduce] [RESULT: starting
the life cycle over again for it 's children]**

Note:

2. **Moderate:** When a tadpole changes into an adult frog , it grows lungs to breath air .

QUANT [WHAT: frog] [COND: adult]
ACTION [ACTION: grows] [OBJ: lungs]
USEDFOR [WHAT: grows lungs] [WHO: it] [FOR: breath air]
ACTION [ACTION: breath] [OBJ: air]
COREF [M1: tadpole] [M2: it]
CHANGE [V: changes] [FROM: tadpole] [TO: adult frog]
**PSTAGE [ACTION: tadpole changes into an adult frog] [RESULT: it grows lungs
to breath air]**

Note:

Examples (PROLE):

1. **Easy:** In a food chain , green plants are producers .

QUANT [WHAT: plants] [COND: green]
PROLE [PROCESS: food chain] [ACTOR: green plants] [ROLE: producers]

Note: Explicit structure (e.g. In PROCESS, ACTORs are ROLE).

2. **Moderate:** The source of wind and water in the weathering process is usually from weather .

LISTAND [W: wind] [X: water]
QUANT [WHAT: wind and water] [COND: in the weathering process]
QUANT [WHAT: process] [COND: weathering]
QUANT [WHAT: weather] [QUANT: usually]
SOURCEOF [WHAT: weather] [SOURCEOF: wind and water in the weathering process]
**PROLE [PROCESS: weathering process] [ACTOR: weather] [ROLE: source of wind
and water]**

Note:

Examples (PLINK):

1. **Easy:** The progression of seasons is Summer , then Autumn , then Winter , then Spring .

QUANT [WHAT: seasons] [COND: progression of]
PLINK [PREVACTION: Summer] [NEXTACTION: Autumn]
PLINK [PREVACTION: Autumn] [NEXTACTION: Winter]
PLINK [PREVACTION: Winter] [NEXTACTION: Spring]
PLINK [PREVACTION: Spring] [NEXTACTION: Summer]
MEANS [X: progression of seasons] [MEANS: Summer , then Autumn , then Winter , then Spring]

Note: An explicit progression of stages of the process that is the changing of the seasons.

2. **Moderate:** Oxygenated blood moves from the lungs to the heart , then from the heart to the rest of the body .

TRANSFER [WHAT: Oxygenated blood] [HOW: moves] [SOURCE: lungs] [DEST: heart]
TRANSFER [SOURCE: heart] [DEST: rest of the body]
QUANT [WHAT: body] [COND: rest of]
PLINK [PREVACTION: Oxygenated blood moves from the lungs to the heart]
[NEXTACTION: from the heart to the rest of the body] QUANT [WHAT: blood]
[COND: Oxygenated]

Note: Links two stages of the process (... blood moving from the lungs to the heart), followed by (from the heart to the rest of the body).

3. **Moderate:** A telephone converts sound into electrical energy , then transmits that electrical energy to another telephone , where it is converted back into sound .

COREF [M1: electrical energy] [M2: electrical energy] [M3: it]
CHANGE [V: converts] [WHAT: telephone] [FROM: sound] [TO: electrical energy]
CHANGE [V: converted] [WHAT: telephone] [FROM: it] [TO: sound]
TRANSFER [WHAT: electrical energy] [HOW: transmits] [SOURCE: A telephone] [DEST: another telephone]
PLINK [PREVACTION: telephone converts sound into electrical energy] [NEXTACTION: then transmits that electrical energy to another telephone]
PLINK [PREVACTION: transmits that electrical energy to another telephone]
[NEXTACTION: where it is converted back into sound]

Note: Long example, multiple stages and their progression/links in a single sentence.

6.5 Annotation Guide: Quantifiers/Scope

The *Quantifier/Scope* knowledge category is a catch-all for modifiers that are not well captured using existing relations.

6.5.1 Quantifier/Scope

Purpose: Quantifier/Scope relations describe modifiers that are not well captured using existing relations.

Specific forms and usages: There is only a single form for this relation.

1. **QUANT** [WHAT] [QUANT] [COND]

ARG WHAT: The thing being quantified/reduced in scope

ARG QUANT: A quantifier, generally describing a numerical or vector quantity

ARG COND: A scope condition or reduction, often through an implicit or explicit prepositional phrase, or otherwise increasing the specificity of the WHAT subject

Examples (Quantifiers):

1. **Easy:** The opposite of good health is poor health .

QUANT [WHAT: health] [QUANT: good]
QUANT [WHAT: health] [QUANT: poor]
OPPOSITEOF [X: good health] [OPPOSITEOF: poor health]

Note: “*Good/poor*” are quantitative measures of *health*.

2. **Moderate:** When a mineral is rubbed on a streak plate , some of the mineral breaks off and forms a powder

ACTION [SUBJ: mineral] [ACTION: rubbed] [OBJ: streak plate]
COREF [M1: mineral] [M2: mineral]
QUANT [WHAT: mineral] [QUANT: some]
CHANGE [V: breaks off] [WHAT: mineral] [TO: powder]
IFTHEN [IF: mineral is rubbed on a streak plate] [THEN: some of the mineral breaks off and forms a powder]

Note: Quantity: How much of the mineral? *Some* of the mineral.

3. **Moderate:** A hurricane is a kind of storm with large amounts of rain and very fast winds .

QUANT [WHAT: winds] [COND: very fast]
QUANT [WHAT: rain] [QUANT: large amounts of]
LISTAND [W: large amounts of rain] [X: very fast winds]
KINDOF [X: hurricane] [KINDOF: kind]
CONTAINS [X: hurricane] [CONTAINS: large amounts of rain and very fast winds]

Note: Quantity: How much rain? *Large amounts of* rain.

Examples (Scope):

1. **Easy):** Wood from trees can be burned to produce heat .

QUANT [WHAT: Wood] [COND: from trees]
 ACTION [SUBJ: Wood] [ACTION: burned]
 GENERATE [V: produce] [WHAT: heat]
 VEHICLE [WHAT: produce heat] [BYTHROUGH: burned]

Note: Reducing scope of "wood" through explicit prepositional phrase. Where is the wood from? *from trees*.

2. **Moderate:** If a prey population decreases , the predator population may decrease .

QUANT [WHAT: population] [COND: prey]
QUANT [WHAT: population] [COND: predator]
 CHANGE [DIR: decreases] [WHAT: prey population]
 CHANGE [DIR: decrease] [WHAT: predator population]
 RELATIONSHIP [COND: prey population decreases] [RESULT: predator population may decrease]

Note: Reducing scope of "population" through implicit prepositional phrase (e.g. population of predators, population of prey).

3. **Moderate:** Temperature is a kind of heat energy .

KINDOF [X: Temperature] [KINDOF: heat energy]
QUANT [WHAT: energy] [COND: heat]

Note: Further specification: Temperature is a kind of energy – What kind of energy? *Heat* energy.

4. **Moderate:** In a food chain , green plants are producers .

QUANT [WHAT: plants] [COND: green]
 PROLE [PROCESS: food chain] [ACTOR: green plants] [ROLE: producers]

Note: Further specification: Which plants? *Green* plants.

5. **Moderate:** A mouse is a kind of walking animal that lives in holes in the ground .

QUANT [WHAT: animal] [COND: walking]
QUANT [WHAT: holes] [COND: in the ground]
QUANT [WHAT: lives] [COND: in holes]
 PROPERTY [WHAT: mouse] [PROP: lives]
 KINDOF [X: mouse] [KINDOF: walking animal]

Note: Nested scope through explicit prepositional phrases: A mouse lives where? *in holes*. Where are these holes? *In the ground*. Similarly, a mouse is what kind of animal? *A walking* animal.

6. **Moderate:** Crumple means to change from a smooth shape to an irregular or compacted shape .

LISTOR [W: irregular] [X: compacted]
QUANT [WHAT: shape] [COND: smooth]
QUANT [WHAT: shape] [COND: irregular or compacted]
 CHANGE [V: change] [FROM: smooth shape] [TO: irregular or compacted shape]

MEANS [X: Crumple] [MEANS: change from a smooth shape to an irregular or compacted shape]

Note: What kind of shape? A *smooth* shape (or, in the other example, an *irregular of compacted* shape).

7. **Moderate:** Covering something is a form of protection against weather , including precipitation and tempeature .

LISTAND [W: precipitation] [X: tempeature]

EXAMPLEOF [X: precipitation and tempeature] [EX_OF: weather]

QUANT [WHAT: protection] [COND: against weather]

ACTION [ACTION: Covering] [OBJ: something]

KINDOF [X: Covering something] [KINDOF: protection]

Note: Reducing scope: Covering is a form of protection. Protection against what? *Against weather*.

This page intentionally left blank.