In library and information science, it is very common to discuss resource descriptions using a classification proposed by Arlene Taylor, which distinguishes administrative, structural, and descriptive metadata. A similar typology proposed by Gilliland breaks metadata down into five types: administrative, descriptive, preservation, use, and technical. Both of these classifications imply a narrow notion of descriptive metadata that reflects the historical emphasis on bibliographic description, in contrast to our view that treats resource description as a more inclusive category. In addition, these classifications do not always distinguish between intrinsic and extrinsic properties (as we will see in §4.3.3, "Identifying Properties" (page 160)), and they often mix and match design and implementation considerations.

Resource description is not an end in itself. Its many purposes are all means for enabling and using an organizing system for some collection of resources. As a result, our framework for resource descriptions aligns with the activities of organizing systems we discussed in Chapter 2: selecting, organizing, interacting with, and maintaining resources.

4.3 The Process of Describing Resources

We prefer the general concept of resource description over the more specialized ones of bibliographic description and metadata because it makes it easier to see the issues that cut across the domains where those terms dominate. In addition, it enables us to propose more standard process that we can apply broadly to the use of resource descriptions in organizing systems. A shared vocabulary enables the sharing of lessons and best practices.

The process of describing resources involves several interdependent and iterative steps. We begin with a generic summary of the process to set the stage for a detailed step-by-step discussion.

1. **Determining Scope and Focus**

   Identifying resources to describe is the first step; this topic is covered in detail in §3.3, "Resource Identity" (page 109). The resource domain and scope circumscribe the describable properties and the possible purposes that descriptions might serve. The resource focus determines which are primary information resources and which ones are treated as the corresponding resource descriptions. Two important decisions at this stage are granularity of description—are we describing individual resources or collections of them?—and the abstraction level—are we describing resource instances, parts of them, or resource types?

2. **Determining Purposes**
Generally, the purpose of resource description is to support the activities common to all organizing systems: selecting, organizing, interacting with, and maintaining resources, as we saw in Chapter 2. The particular resource domain and the context in which descriptions are created and used imposes more specific requirements and constraints on the purposes that resource description can serve.

3. **Identifying Resource Properties**
   Once the purposes of description in terms of activities and interactions have been determined, the specific properties of the resources that are needed to enable them can be identified. The contrasts between intrinsic and extrinsic properties, and between static and dynamic properties, are useful to identify appropriate resource properties.

4. **Designing the Description Vocabulary**
   This step includes several logical and semantic decisions about how the resource properties will be described. What terms or element names should be used to identify the resource properties we have chosen to describe? Are there rules or constraints on the types of data or values that the property descriptions can assume? A good description vocabulary will be easy to assign when creating resource descriptions and easy to understand when using them.

5. **Designing the Description Form and Implementation**
   The logical and semantic decisions about the description vocabulary are reified by decisions about the notation, syntax and structure of the descriptions. Taken together, these decisions collectively determine what we call the **form** or **encoding** of the resource descriptions. The implementation of the descriptions involves decisions about how and where they are stored and the technology used to create, edit, store, and retrieve them.

6. **Creating the Descriptions**
   Resource descriptions are created by individuals, by informal or formal groups of people, or by automated or computational means. Some types of descriptions can only be created by people, some types of descriptions can only be created by automated or algorithmic techniques, and some can be created in either manner.

7. **Evaluating the Descriptions**
   The resource descriptions must be evaluated with respect to their intended purposes. The results of this evaluation will help determine which or the preceding steps need to be redone.

The next seven sub-sections discuss each of these steps in detail. A quick reference guide is Figure 4.3, “The Process of Describing Resources.”
Figure 4.3. The Process of Describing Resources.

How explicit and systematic each step needs to be depends on the resource domain and scope, and especially on the intended users of the organizing system. If we look carefully, we can see most of these steps taking place even in very informal contexts, like the kids playing with Lego blocks with which we started this chapter. The goal of building things with the blocks leads the boys to identify which properties are most useful to analyze. They develop descriptions of the blocks that capture the specific values of the relevant properties. Finally, they evaluate their descriptions by using them when they play together; it becomes
immediately obvious that a description is not serving its purpose when one boy hands a block to another that was not the one he thought he had asked for.

In contrast, the picture-taking scenario involves a much more explicit and systematic process of resource description. The resource properties, description vocabulary, and description form used automatically by the digital camera were chosen by an industry association and published as a technical specification implemented by camera and mobile phone manufacturers worldwide. If a professional photographer is taking the photo for commercial purposes, many of the other descriptions assigned to the image to identify ownership, rights management and syndication are likely to conform to formal specifications and be managed in institutional information systems.

The resource descriptions used by libraries, archives, and museums are typically created in an even more explicit and systematic manner. Like the descriptions of the digital photo, the properties, vocabulary, and form of the descriptions used by their organizing systems are governed by standards. However, there is no equivalent to the digital camera that can create these descriptions automatically. Instead, highly trained professionals create them meticulously.

A great many resources and their associated descriptions in business and scientific organizing systems are created by automated or computational processes, so the process of describing individual resources is not at all like that in libraries and other memory institutions. However, the process for designing the data models or schemas for the class of resources that will be generated is equally systematic and is typically performed by highly skilled data analysts and data modelers.

4.3.1 Determining the Scope and Focus

Which resources do we want to describe? As we saw in Chapter 3, determining what will be treated as a separate resource is not always easy, especially for resources with component parts and for information resources where the most important property is their content, which is not directly perceivable. Identifying the thing you want to describe as precisely as practical is the first step to creating a useful description.

In §3.2.4, “Resource Focus” (page 106), we introduced the contrast between primary resources and description resources, which we called resource focus. Determining the resource focus goes hand in hand with determining which resources we intend to describe; these often arbitrary decisions then make a huge difference in the nature and extent of resource description. One person’s metadata is another person’s data. For a librarian, the price of a book might be just one more attribute that is part of the book’s record. For an accountant at a bookstore, the price of that book—both the cost to buy the book and the price at
which it is then sold to customers—is critical information for staying in business. A scientist studying comparative anatomy preserves animal specimens and records detailed physical descriptions about them, but a scientist studying ecology or migration discards the specimens and focuses on describing the context in which the specimen was located.

### 4.3.1.1 Describing Instances or Describing Collections

It is simplest to think of a resource description as being associated with another individual resource. However, as discussed in Chapter 3, it can be challenging to determine what to treat as an individual resource when resources are themselves objects or systems that are composed of other parts or resources. For example, we sometimes describe a football team as a single resource and at other times we focus on each individual player. However, after we have decided on resource granularity, the question remains whether each resource needs a separate description.

Libraries and museums specialize in curating resource descriptions about the instances in their collections. Resource descriptions are also applied to classes or collections of resources (because a collection is also a resource; see §1.2.2, “The Concept of “Collection”” (page 10)). Archives and special collections of maps are typically assigned resource descriptions, but each document or map contained in the collection does not necessarily have its own bibliographic description. Similarly, business and scientific data sets are invariably described at collection-level granularity because they are often analyzed in their entirety.

Furthermore, the granularity of description for a collection of resources tends to differ for different users or purposes. Consider the information systems that commodity traders use to access descriptions of real resources in markets all over the world: some traders are concerned with weekly production in their region, while others are monitoring real-time global flows of precious metals and petroleum products. Many web pages, especially e-commerce product catalogs and news sites, are dynamically assembled and personalized from a large number of information resources and services that are separately identified and described in content management and content delivery systems. However, a highly complex collection of resources that comes together in a single page is treated as a single resource when that page appears in a list of search engine results. Moreover, all of the thousands of separately generated pages can be given a single description when a user creates a bookmark to make it easy to return to the home page of the site.

### 4.3.1.2 Abstraction in Resource Description

We can also associate resource descriptions with an entire type or domain of resources (see §2.5.2.4, “Preserving Resource Types” (page 73) and §3.2.1, “Re-
source Domain” (page 100)). A collection of resource descriptions is vastly more useful when every resource is described using common description elements or terms that apply to every resource. A schema (or model, or metadata standard) specifies the set of descriptions that apply to an entire resource type. Sometimes this schema, model, or standard is inferred from or imposed on a collection of existing resources to ensure more consistent definitions, but more often, it is used as a specification when the resources are created or generated in the first place (See “What about “Creating” Resources?” (page 50) in §2.1, “Introduction” (page 47)).

A relational database, for example, is easily conceptualized as a collection of records organized as one or more tables, with each record in its own row having a number of fields or attributes that contain some prescribed type of content. Each record or row in the database table is a description of a resource—an employee, a product, anything—and the individual attribute values, organized by the columns and rows of the table, are distinct parts of the description for some particular resource instance, like employee 24 or product 8012C.

Because the relational database schema serves as a model for the creation of resource descriptions, it is designed to restrict the descriptions to be simple and completely regular sets of attribute-value pairs. The database schema specifies the overall structure of the tables and especially their columns, which will contain the attribute values that describe each resource. An employee table might have columns for the attributes of employee ID, hiring date, department, and salary. A date attribute will be restricted to a value that is a date, while an employee salary will be restricted according to salary ranges established by the human resources department. This makes the name of the attribute and the constraints on attribute values into resource descriptions that apply to the entire class of resources described by the table.

The information resources that we commonly call documents are, by their nature, less homogeneous in content and structure than those that can be managed in databases. Document schemas, commonly represented in SGML or XML, usually allow for a mixture of data-like and textual descriptive elements. XML schema languages have greatly improved on SGML and XML by expressing the description of the document schema in XML itself, using the same syntax as the resource it describes, making it easy to create resources using the metadata as a template or pattern. As a result, XML schemas are often used as the specifications for XML resources created and used by information-intensive applications; in this context, they are often called XML vocabularies. XML schemas are often used to define web forms that capture resource instances (each filled-out form). XML schemas are also used to describe the interfaces to web services and other computational resources.\textsuperscript{207}
It is often necessary to associate some descriptions with individual resources that are specific to that instance and other kinds of descriptions that reflect the abstract class to which the instance belongs. When a typical car comes off the assembly line, it has only one instance-level description that differentiates it from its peers: its vehicle identification number (VIN). Specific cars have individualized interior and exterior colors and installed options, and they all have a date and location of manufacture. Other description elements have values that are shared with many other cars of the same model and year, like suggested price and the additional option packages, or configurations that can be applied to it before it is delivered to a customer. Alternatively, any descriptive information that applies to multiple cars of the same model year could be part of a resource description at that level that is referred to rather than duplicated in instance descriptions.

4.3.1.3 Scope, Scale, and Resource Description

If we only had one thing to describe, we could use a single word to describe it: "it." We would not need to distinguish it from anything else. A second resource implies at least one more term in the description language: "not it." However, as a collection grows, descriptions must become more complex to distinguish not only between, but also among resources.

Every element or term in a description language creates a dimension, or axis, along which resources can be distinguished, or it defines a set of questions about resources. Distinctions and questions that arise frequently, such as "what is the name of the resource?", "who created it?", or "what type of content or matter does it contain?", need to be easy to address. Therefore, as a collection grows, the language for describing resources must become more rigorous, and descriptions created when the collection was small often require revision because they are no longer adequate for their intended purposes. The description language typically evolves from a simple list of descriptive terms to a glossary with definitions, to a highly controlled vocabulary with content rules for allowable values, and, finally, to a thesaurus in which each term is also defined with respect to its semantic relationships to other terms that are broader, narrower, or otherwise associated with it.\(^{208}\)

This co-evolution of descriptive scope and description complexity is easy to see in the highly complex bibliographic descriptions created by professional catalogers. The commonly used AACR2 cataloging standards distinguish 11 different categories of resources and specify several hundred descriptive elements.\(^{209}\) Because the task of library resource description has been standardized at national and international levels, cataloging work is distributed among many describers whose results are shared. This principle of standardization has been the basis of centralized bibliographic description for a century.
Centralized resource description by skilled professionals works for libraries, but even in the earliest days of the web many library scientists and web authoring futurists recognized that this approach would not scale for describing web resources. In 1995, the Dublin Core metadata element set with only 15 elements was proposed as a vastly simpler description vocabulary that people not trained as professional catalogers could use. Since then, the Dublin Core initiative has been highly influential in inspiring numerous other communities to create minimalist description vocabularies, often by simplifying vocabularies that had been devised by professionals for use by non-professionals. In this respect, we can also view the Dublin Core as part of the intellectual foundations for the “crowdsourcing” or “community curation” of resource descriptions by non-professionals (§2.5.3.3, “Social and Web Curation” (page 75)).

Of course, a simpler description vocabulary makes fewer distinctions than a complex one; replacing “author,” “artist,” “composer” and many other descriptions of the person or non-human resource responsible for the intellectual content of a resource with just “creator” results in a substantial loss of precision when the description is created and can cause misunderstanding when the descriptions are reused.

The negative impacts of growing scope and scale on resource description can sometimes be avoided if the ultimate scope and scale of the organizing system is contemplated when it is being created. It would not be smart for a business with customers in six US states to create an address field in its customer database that only handled those six states; a more extensible design would allow for any state or province and include a country code. In general, however, just as there are problems in adapting a simple vocabulary as scope and scale increase, designing and applying resource descriptions that will work for a large and continuously growing collection might seem like too much work when the collection at hand is small.

4.3.2 Determining the Purposes

Resource description serves many purposes, and the mix of purposes and the resulting kinds of descriptions in any particular organizing system depends on the scope and scale of the resources being organized. We can identify and classify the most common purposes using the four activities that occur in every organizing system: selecting, organizing, interacting with, and maintaining resources (see Chapter 2).

4.3.2.1 Resource Description to Support Selection

Defining selection as the process by which resources are identified, evaluated, and then added to a collection in an organizing system emphasizes resource descriptions created by someone other than the person who is using them. We can
distinguish several different ways in which resource description supports selection:

**Discovery**
What resources are available that might be added to a collection? New resources are often listed in directories, registries, or catalogs. Some types of resources are selected and acquired automatically through subscriptions or contracts.

**Capability and Compatibility**
Will the resource meet functional or interoperability requirements? Technology-intensive resources often have numerous specialized types of descriptions that specify their functions, performance, reliability, and other "ilities" that determine if they fit in with other resources in an organizing system. Some services have qualities of service levels, terms and conditions, or interfaces documented in resource descriptions that affect their compatibility and interoperability. Some resources have licensing or usage restrictions that might prevent the resources from being used effectively for the intended purposes.

**Authentication**
Is the resource what it claims to be? (§3.5.3, “Authenticity” (page 126)). Resource descriptions that can support authentication include technological ones like time stamps, watermarking, encryption, checksums, and digital signatures. The history of ownership or custody of a resource, called its provenance (§3.5.4, “Provenance” (page 126)), is often established through association with sales or tax records. Import and export certificates associated with the resource might be required to comply with laws designed to prevent the theft of antiquities or the transfer of technology or information with national security or foreign policy implications.

**Appraisal**
What is the value of this resource? What is its cost? At what rate does it depreciate? Does it have a shelf life? Does it have any associated ratings, rankings, or quality measures? Moreover, what is the quality of those ratings, rankings and measures?

We can also take the perspective of the person creating the resource description and consider his or her primary purpose, which is often to encourage the selection of the resource by someone else. This is what product marketing is about—devising names and descriptions to make a resource distinctive and attractive compared to alternatives. A fish once known as the Patagonian Toothfish became popular in American restaurants when a fish wholesaler began marketing it as the Chilean Sea Bass. Apple has consistently described its products to emphasize experiential or cultural properties, as compared with Intel or other PC manufacturers, whose descriptions emphasize technical specifications.
4.3.2.2 Resource Description to Support Organizing

Often, the activities of organizing resources and designing interactions with them are intertwined, but they are logically separate. We define organizing as specifying the principles or rules for describing and arranging resources in order to create the capabilities on which interactions are based. This lets us treat the design and implementation of resource interactions as if those were separate and subsequent activities. For example, assigning keywords to documents that describe their contents is an organizing activity, while designing and implementing an information retrieval application that uses the keywords is the design of resource interactions.

Physical resources are often organized according to their tangible or perceivable properties like size, color, material of composition, or shape (§2.3.1.1, "Organizing with Properties of Physical Resources" (page 56)). For other types of physical resources, however, such as hazardous materials, it is the descriptions and not the directly perceivable properties that determine or constrain how the resources are organized (§2.3.1.2, "Organizing with Descriptions of Physical Resources" (page 57)). Similarly, building codes or other regulations associated with physical resources can prescribe or prohibit particular resource arrangements. Rules governing the collection, integration, and analysis of personal information are also resource descriptions that influence the organization of information resources.

Any types of resources that have sortable identifiers can be organized using that descriptive element.

4.3.2.3 Resource Description to Support Interactions

Most discussions of the purposes of resource descriptions and metadata emphasize the interactions that are based on resource descriptions that have been intentionally and explicitly assigned. For bibliographic resources these interactions and the models of resource descriptions needed to support them have been formalized as the Functional Requirements for Bibliographic Records (FRBR). FRBR presents four purposes that apply generically to organizing systems, not just bibliographic ones: Finding, Identifying, Selecting, and Obtaining resources.

Finding

What resources are available that "correspond to the user's stated search criteria" and thus can satisfy an information need? Before there were online catalogs and digital libraries, we found resources by referencing catalogs of printed resource descriptions incorporating the title, author, and subject terms as access points into the collection; the subject descriptions were the most important finding aids when the user had no particular resource in mind. Modern users accept that computerized indexing makes search possi-
ble over not only the entire description resource, but often over the entire content of the primary resource. Businesses search directories for descriptions of company capabilities to find potential partners, and they also search for descriptions of application interfaces that enable them to exchange information in an automated manner.

**Identifying**
Another purpose of resource description is to enable a user to confirm the identity of a specific resource or to distinguish among several that have some overlapping descriptions. In bibliographic contexts this might mean finding the resource that is identified by its citation. Computer processable resource descriptions like bar codes, QR codes, or RFID tags are also used to identify resources. In Semantic Web contexts, URIs serve this purpose.

**Selecting**
The user activity of using resource descriptions to support a choice of resource from a collection, not the institutional activity of selecting resources for the collection in the first place. Search engines typically use a short “text snippet” with the query terms highlighted as resource descriptions to support selection. People often select resources with the least restrictions on uses as described in a Creative Commons license. A business might select a supplier or distributor that uses the same standard or industry reference model to describe its products or business processes because it is almost certain to reduce the cost of doing business with that business partner.

**Obtaining**
Physical resources often require significant effort to obtain after they have been selected. Catching a bus or plane involves coordinating your current location and time with the time and location the resource is available. With information resources in physical form, obtaining a selected resource usually meant a walk through the library stacks. With digital information resources, a search engine returns a list of the identifiers of resources that can be accessed with just another click, so it takes little effort to go from selecting among the query results to obtaining the corresponding primary resource.

Elaine Svenonius proposed that a fifth task be added to the FRBR list:

**Navigation**
If users are not able to specify their information needs in a way that the “finding” functionality requires, they should be able to use relational and structural descriptions among the resources to navigate from any resource to other ones that might be better. Svenonius emphasizes generalization, aggregation, and derivational relationships. But in a truly semantic web, any relationship or property could serve as the navigation “highway” between resources.
What some authors call “structural metadata” can be used to support the related tasks of moving within multi-part digital resources like electronic books, where each page might have associated information about previous, next, and other related pages. Documents described using XML models can use XSLT and XPath to address and select data elements, sub-trees, or other structural parts of the document.220

The FRBR framework is the most recent formalization of the purposes of resource description that started in nineteenth century libraries.221 This long history means it is not surprising that how we think about resource description still shows some bias toward interactions with physical bibliographic resources and the descriptions needed to obtain them. With physical resources, any interactions that take place once the primary resources are obtained are outside the scope of the organizing system because they are not directly supported by it.

With digital resources, on the other hand, many of the purposes of resource description are realized with the primary resources. These purposes usually involve processing of the resource content and structure: analysis, summarization, visualization, transformation, reuse, mixing, remixing... far too many purposes to list here. The core principle that underlies all of these purposes is that the variety and functions of the interactions with digital resources depends on the richness of their structural, semantic, and format description (See §2.4.2.2, “Value Creation with Digital Resources” (page 64)).

An important difference between interactions with physical resources and those with digital resources is how they use resource descriptions for access control. Resources sometimes have associated security classifications like “Top Secret” that restrict who can learn about their existence or obtain them. Nonetheless, if you get your hands on a top secret printed document, nothing can prevent you from reading it. Similarly, printed resources often have “All rights reserved” copyright notices that say that you cannot copy them, but nothing can prevent you from making copies with a copy machine. On the other hand, learning of the existence of a digital resource might be of little value if copyright or licensing restrictions prevent you from obtaining it. Moreover, obtaining a digital resource might be of no value if its content is only available using a password, decryption key, or other resource description that enforces access control directly rather than indirectly like the security classifications.

Another important difference between physical resources and digital ones is that interactions with the latter are easily recorded. Usage records from session logs, browsing, or downloading activities are resource descriptions that can be tied to payments for using the resources or analyzed to influence the selection and organizing of resources in future interactions.

4.3 The Process of Describing Resources
4.3.2.4 Resource Description to Support Maintenance

Many types of resource descriptions that support selection (§4.3.2.1, "Resource Description to Support Selection" (page 155)) are also useful over time to support maintenance of specific resource and the collection to which they belong. In particular, technical information about resource formats and technology (software, computers, or other) needed to use the resources, and information needed to ensure resource integrity is often called "preservation metadata" in a maintenance context.222

Other types of resource descriptions more exclusively associated with maintenance activities include version information and effectivity or useful life information. Usage records are also valuable because they enable the identification of resources that are not being accessed, suggesting that they are no longer needed and can thus be safely archived or discarded.

4.3.3 Identifying Properties

Once the purposes of description have been established, we need to identify the specific properties of the resources that can satisfy those purposes. There are four reasons why this task is more difficult than it initially appears.

First, any particular resource might need many resource descriptions, all of which relate to different properties, depending on the interactions to be supported and the context in which they take place. Think about how we might describe something as simple as a chair. In your house, you might describe your chair based on the room it is in, e.g., "the kitchen chair." When you take the same chair to a potluck dinner at a friend's house, where all the chairs end up in the kitchen, it becomes "my chair," or "the wooden chair," or "the folding chair," or "the black chair with white trim." Maybe you inherited it, so when you talk to your family, you call it "grandma's chair." If you decide to sell it, you will describe it in a way that is intended to encourage someone to buy it, as an "all-oak antique kitchen chair in mint condition."

Second, different types of resources need to incorporate different properties in their descriptions. For resources in a museum, these might include materials and dimensions of pieces of art; for files and services managed by a network administrator, these include access control permissions; for electronic books or DVDs, they would include the digital rights management (DRM) code that expresses what you can and cannot do with the resource.

Third, as we briefly touched on in §4.3.1.3, "Scope, Scale, and Resource Description" (page 154), which properties participate in resource descriptions depends on who is doing the describing. It makes little sense to expect fine-grained distinctions and interpretations about properties from people who lack training in the discipline of organizing. We will return to this tradeoff in §4.3.6,
"Creating Resource Descriptions" (page 168) and again in §4.4.1, "Describing Museum and Artistic Resources" (page 173).

Fourth, what might seem to be the same property at a conceptual level might be very different at an implementation level. Many types of resources have a resource description that is a surrogate or summary in some respects of the primary resource. For photos, paintings, and other resources whose appearance is their essence, an appropriate summary description can be a smaller, reduced resolution or thumbnail photo of the original. This surrogate is simple to create and it is easy for users to understand its relationship to the primary resource. On the other hand, distilling a text down to a short summary or abstract is a skill unto itself. Time-based resources provide greater challenges for summary. Should the summary of a movie be a textual summary of the plot, a significant clip from the movie, a video summary, or something else altogether? How is a song summarized? Or a poem? Or a tree?

Two important dimensions for understanding and contrasting resource properties used in descriptions and organizing principles are property essence—whether the properties are intrinsically or extrinsically associated with the resource, and property persistence—the properties are static or dynamic. Taken together these two dimensions yield four categories of properties, as illustrated in Figure 4.4, "Property Essence x Persistence: Four Categories of Properties."

4.3.3.1 Intrinsic Static Properties

Intrinsic or implicit properties are inherent in the resource and can often be directly perceived or experienced. Static properties do not change their values over time. The size, color, shape, weight, material of composition, and texture of natural or manufactured objects are intrinsic and static properties that are often used to describe and organize physical resources. If a particular Lego is blue, it is set apart from all the not-blue Legos; a square Lego is physically different from a round one. When bibliographic resources were exclusively physical, their sizes and their number of pages were common physical properties in their descriptions.

Intrinsic physical properties are usually just part of resource descriptions. In many cases, physical properties describe only the surface layer of a resource, revealing little about what something is or its original intended purpose, what it means, or when and why it was created. These intrinsic static properties cannot be directly perceived. The author or creator of a resource, the context of its creation, and the duration of a song are other examples of intrinsic and static resource properties.

Intrinsic descriptions are often extracted or calculated by computational processes. For example, a computer program might calculate the frequency and distribution of words in some particular document. Those statistics about con-
<table>
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<th>Property Essence</th>
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<tbody>
<tr>
<td><strong>Intrinsic</strong></td>
<td><strong>Extrinsic</strong></td>
</tr>
<tr>
<td><strong>Static</strong></td>
<td><strong>Static</strong></td>
</tr>
<tr>
<td><em>Intrinsic Static</em></td>
<td><em>Extrinsic Static</em></td>
</tr>
<tr>
<td><strong>Definition:</strong> Directly experienced, subject matter, implicit, inherent properties.</td>
<td><strong>Definition:</strong> Assigned to resource, name, identifier.</td>
</tr>
<tr>
<td><strong>Examples:</strong> Size, color, shape, author, date of creation.</td>
<td><strong>Examples:</strong> Dewey decimal</td>
</tr>
<tr>
<td><img src="image" alt="Square" /> <img src="image" alt="Triangle" /> <img src="image" alt="Circle" /></td>
<td><img src="image" alt="Book" /></td>
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<tr>
<td><strong>Dynamic</strong></td>
<td><strong>Dynamic</strong></td>
</tr>
<tr>
<td><em>Intrinsic Dynamic</em></td>
<td><em>Extrinsic Dynamic</em></td>
</tr>
<tr>
<td><strong>Definition:</strong> Inherent properties; change over time.</td>
<td><strong>Definition:</strong> Behavioral and contextual properties</td>
</tr>
<tr>
<td><strong>Examples:</strong> Skills, experience</td>
<td><strong>Examples:</strong> Current owner, location, best seller lists.</td>
</tr>
<tr>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Flowchart" /></td>
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*Figure 4.4. Property Essence x Persistence: Four Categories of Properties.*

tent properties would still be intrinsic descriptions even though an external process creates them. Similarly, “image signatures” or “audio fingerprints” are intrinsic descriptions (§4.4, “Describing Non-Text Resources” (page 173)).

Some relationships among resources are intrinsic and static, like the parent-child relationship or the sibling relationship between two children with the same parents. Part-whole or compositional relationships for resources with parts, both physical ones like manufactured objects and digital ones like hierarchical documents or databases, are also intrinsic static properties often used in resource descriptions. However, it is better to avoid treating resource relationships as properties, and instead express them as relations. Chapter 5, “Describing Relationships and Structures” discusses part-whole and other semantic relationships in great detail.
4.3.3.2 Extrinsic Static Properties

Extrinsic or explicit properties are assigned to a resource rather than being inherent in it. The name or identifier of a resource is often arbitrary but once assigned does not usually change. Arranging resources according to the alphabetical or numerical order of their descriptive identifiers is a common organizing principle. Classification numbers and subject headings assigned to bibliographic resources are extrinsic static properties, as are the serial numbers stamped on or attached to manufactured products.

For information resources that have a digital form, the properties of their printed or rendered versions might not be intrinsic. Some text formats completely separate content from presentation, and as a result, style sheets can radically change the appearance of a printed document or web page without altering the primary resource in any way. For example, were a different style applied to this paragraph to highlight it in bold or cast in 24-point font, its content would remain the same.

4.3.3.3 Intrinsic Dynamic Properties

Intrinsic dynamic properties change over time, such as developmental personal characteristics like a person’s height and weight, skill proficiency, or intellectual capacity. Because these properties are not static, they are usually employed only to organize resources whose membership in the collection is of limited duration. Sports programs or leagues that segregate participants by age or years of experience are using intrinsic dynamic properties to describe and organize the resources.

4.3.3.4 Extrinsic Dynamic Properties

Extrinsic dynamic properties are in many ways arbitrary and can change because they are based on usage, behavior, or context. The current owner or location of a resource, its frequency of access, the joint frequency of access with other resources, its current popularity or cultural salience, or its competitive advantage over alternative resources are typical extrinsic and dynamic properties that are used in resource descriptions. A topical book described as a best seller one year might be found in the discount sales bin a few years later. A student’s grade point average is an extrinsic dynamic property.

Many relationships between resources are extrinsic and dynamic properties, like that of best friend.

Resources are often described with **cultural properties** that derive from conventional language or culture, often by analogy, because they can be highly evocative and memorable. For the Lego boys familiar with the Star Wars movies, “light saber” was just the obvious word for a long, neon tube with a handle.
However, someone who has never seen or heard of *Star Wars* would not understand this description, and he would describe the piece some other way. Sometimes a cultural description lasts longer than its salience, so it loses its power to evoke anything other than puzzlement about what it might mean.²²³

**Contextual properties** are those related to the situation or context in which a resource is described. Dey defines context as “any information that characterizes a situation related to the interactions between users, applications, and the surrounding environment.”²²⁵ This open-ended definition implies a large number of contextual properties that might be used in a description; crisper definitions of context might be “location + activity” or “who, when, where, why.” Since context changes, context-based descriptors might be appropriate when assigned but can have limited persistence and effectivity (§3.5, “Resources over Time” (page 123)); the description of a document as “receipt of a recent purchase” will not be useful for very long.

Citations of one information resource by another are extrinsic static descriptions when they are in print form, but when they are published in digital libraries it is usually the case that “cited by” is a dynamic resource description. Similarly, any particular link from one web page to another is an extrinsic static description, but because many web pages themselves are highly dynamic, we can also consider links as dynamic as well. Citations and web links are discussed in more detail in Chapter 5.

### 4.3.4 Designing the Description Vocabulary

After we have determined the properties to use in resource descriptions, we need to design the description vocabulary: the set of words or values that represent the properties. §3.4, “Naming Resources” (page 116) discussed the problems of naming and proposed principles for good names, and since names are a very important resource description, much of what we said there applies generally to the design of the description vocabulary.

However, because the description vocabulary as a whole is much more than just the resource name, we need to propose additional principles or guidelines for this step. In addition, some new design questions arise when we consider all the resource descriptions as a set whose separate descriptions are created by many people over some period of time.

#### 4.3.4.1 Principles of Good Description

In *The Intellectual Foundation of Information Organization*, Svenonius proposes a set of principles or “directives for design” of a description language.²²⁶ Her principles, framed in the narrow context of bibliographic descriptions, still apply to the broad range of resource types we consider in this book.
User Convenience
Choose description terms with the user in mind; these are likely to be terms in common usage among the target audience.

Representation
Use descriptions that reflect the how the resources describe themselves; assume that self-descriptions are accurate.

Sufficiency and Necessity
Descriptions should have enough information to serve their purposes and not contain information that is not necessary for some purpose; this might imply excluding some aspects of self-descriptions that are insignificant.

Standardization
Standardize descriptions to the extent practical, but also use aliasing to allow for commonly used used terms.

Integration
Use the same properties and terms for all types of resources whenever possible.

Any set of general design principles faces two challenges. The first is that implementing any principle requires many additional and specific context-dependent choices for which the general principle offers little guidance. For example, how does the principle of Standardization apply if multiple standards already exist in some resource domain? Which of the competing standards should be adopted, and why? The second challenge is that the general principles can sometimes lead to conflicting advice. The User Convenience recommendation to choose description terms in common use fails if the user community includes both ordinary people and scientists who use different terms for the same resources; whose “common usage” should prevail?

4.3.4.2 Who Uses the Descriptions?
Focus on the user of the descriptions. This is a core idea that we cannot overemphasize because it is implicit in every step of the process of resource description. All of the design principles in the previous section share the idea that the design of the description vocabulary should focus on the user of the descriptions. Are the resources being organized personal ones, for personal and mostly private purposes? In that case, the description properties and terms can be highly personal or idiosyncratic and still follow the design principles.

Similarly, when resource users share relevant knowledge, or are in a context where they can communicate and negotiate, if necessary, to identify the resources, their resource descriptions can afford to be less precise and rigorous than they might otherwise need to be. This helps explain the curious descriptions in the Lego story with which we began this chapter. The boys playing with the
blocks were talking to each other with the Legos in front of them. If they had not been able to see the blocks the others were talking about, or if they had to describe their toys to someone who had never played with Legos before, their descriptions would have been quite different.

More often, however, resource descriptions can not assume this degree of shared context and must be designed for user categories rather than individual users: library users searching for books, business employees or customers using part and product catalogs, scientists analyzing the datasets from experiments or simulations. In each of these situations resource descriptions will need to be understood by people who did not create them, so the design of the description vocabulary needs to be more deliberate and systematic to ensure that its terms are unambiguous and sufficient to ensure reliable context-free interpretation. A single individual seldom has the breadth of domain knowledge and experience with users needed to devise a description vocabulary that can satisfy diverse users with diverse purposes. Instead, many people working together typically develop the required description vocabulary. We call the results institutional vocabularies, to contrast them with individual or cultural ones (We will discuss this contrast more fully in Chapter 6, "Categorization: Describing Resource Classes and Types").

Some resource descriptions are designed to be used by computers or other machines, which seemingly reduces the importance of design principles that consider user preferences or common uses. However, the Standardization and Integration principles become more important for inter-machine communication because they enable efficient processing, reuse of data and software, and increased interoperability between organizing systems.

4.3.4.3 Controlled Vocabularies and Content Rules

As we defined in §3.4.3.2, a **controlled vocabulary** is a fixed or closed set of description terms in some domain with precise definitions that is used instead of the vocabulary that people would otherwise use. For example, instead of the popular terms for descriptions of diseases or symptoms, medical researchers and teaching hospitals can use the National Library of Medicine controlled vocabulary (MeSH).

We can distinguish a progression of vocabulary control: a glossary is a set of allowed terms; a thesaurus is a set of terms arranged in a hierarchy and annotated to indicate terms that are preferred, broader than, or narrower than other terms; an ontology expresses the conceptual relationships among the terms in a formal logic-based language so they can be processed by computers. We will say more about ontologies in Chapter 5.

**Content rules** are similar to controlled vocabularies because they also limit the possible values that can be used in descriptions. Instead of specifying a fixed set
Chapter 5
Describing Relationships and Structures

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5.1 Introduction

We can consider a family to be a collection of people affiliated by some connections with each other such as common ancestors or a common residence. The Simpson family includes a man named Homer and a woman named Marge, the married parents of three sibling children, a boy named Bart and two girls, Lisa and Maggie. This is a magical family that speaks many languages, but always uses the language of the local television station. In the English-speaking Simpson family, the boy describes his parents as his father and mother and his two siblings as his sisters. In the Spanish speaking Simpson family the boy refers to his parents as su padre y su madre and his sisters are las hermanas. In the Chi-
nese Simpson family Lisa and Maggie refer to each other according to their relative ages; Lisa, the elder sister as jiě jie and, Maggie, the younger sister as měi mei.253

Kinship relationships are ubiquitous and widely studied, and the names and significance of kinship relations like “is parent of” or “is sibling of” are familiar ones, making kinship a good starting point for understanding relationships in organizing systems.254 An organizing system can make use of existing relationships among resources, or it can create relationships by applying organizing principles to arrange the resources. Organizing systems for digital resources or digital description resources are the most likely to rely on explicit relationships to enable interactions with the resources.

In a classic book called Data and Reality, William Kent defines a relationship as “an association among several things, with that association having a particular significance.”255 “The things being associated,” the components of the relationship, are people in kinship relationships but more generally can be any type of resource (Chapter 3), when we relate one resource instance to another. When we describe a resource (Chapter 4), the components of the relationship are a primary resource and a description resource. If we specify sets of relationships that go together, we are using these common relationships to define resource types or classes, which more generally are called categories (Chapter 6). We can then use resource types as one or both the components of a relationship when we want to further describe the resource type or to assert how two resource types go together to facilitate our interactions with them.

We begin with a more complete definition of relationship and introduce five perspectives for analyzing them: semantic, lexical, structural, architectural, and implementation. We then discuss each perspective, introducing the issues that each emphasizes, and the specialized vocabulary needed to describe and analyze relationships from that point of view. We apply these perspectives and vocabulary to analyze the most important types of relationships in organizing systems.

5.2 Describing Relationships: An Overview

The concept of a relationship is pervasive in human societies in both informal and formal senses. Humans are inescapably related to generations of ancestors, and in most cases they also have social networks of friends, co-workers, and casual acquaintances to whom they are related in various ways. We often hear that our access to information, money, jobs, and political power is all about “who you know,” so we strive to “network” with other people to build relationships that might help us expand our access. In information systems, relationships between resources embody the organization that enables finding, selection, retrieval, and other interactions.
Most organizing systems are based on many relationships to enable the system to satisfy some intentional purposes with individual resources or the collection as a whole. In the domain of information resources, common resources include web pages, journal articles, books, data sets, metadata records, and XML documents, among many others. Important relationships in the information domain that facilitate purposes like finding, identifying, and selecting resources include “is the author of,” “is published by,” “has publication date,” “is derived from,” “has subject keyword,” “is related to,” and many others.

When we talk about relationships we specify both the resources that are associated along with a name or statement about the reason for the association. Just identifying the resources involved is not enough because several different relationships can exist among the same resources; the same person can be your brother, your employer, and your landlord. Furthermore, for many relationships the directionality or ordering of the participants in a relationship statement matters; the person who is your employer gives a paycheck to you, not vice versa. Kent points out that when we describe a relationship we sometimes use whole phrases, such as “is-employed-by,” if our language does not contain a single word that expresses the meaning of the relationship.

We can analyze relationships from several different perspectives:

**Semantic perspective**

The semantic perspective is the most essential one; it characterizes the meaning of the association between resources.

**Lexical perspective**

The lexical perspective focuses on how the conceptual description of a relationship is expressed using words in a specific language.

**Structural perspective**

The structural perspective analyzes the actual patterns of association, arrangement, proximity, or connection between resources.

**Architectural perspective**

The architectural perspective emphasizes the number and abstraction level of the components of a relationship, which together characterize its complexity.

**Implementation perspective**

The implementation perspective considers how the relationship is implemented in a particular notation and syntax and the manner in which relationships are arranged and stored in some technology environment.

The remainder of this chapter is organized around a discussion of these five perspectives in the order listed here.
5.3 The Semantic Perspective

In order to describe relationships among resources, we need to understand what the relations mean. This *semantic perspective* is the essence of relationships and explains why the resources are related, relying on information that is not directly available from perceiving the resources.\(^{256}\) In our Simpson family example, we noted that Homer and Marge are related by marriage, and also by their relationship as parents of Bart, Lisa, and Maggie, and none of these relationships are directly perceivable.

Semantic relationships are commonly expressed with a predicate with one or more arguments. A *predicate* is a verb phrase template for specifying properties of objects or a relationship among objects. In many relationships the predicate is an action or association that involves multiple participants that must be of particular types, and the arguments define the different roles of the participants.\(^{257}\)

We can express the relationship between Homer and Marge Simpson using a *predicate(argument(s))* syntax as follows:

**is-married-to (Homer Simpson, Marge Simpson)**

The sequence, type, and role of the arguments are an essential part of the relationship expression. The sequence and role are explicitly distinguished when predicates that take two arguments are expressed using a *subject-predicate-object* syntax that is often called a *triple* because of its three parts:

**Homer Simpson → is-married-to → Marge Simpson**

However, we have not yet specified what the “is-married-to” relationship means. People can demonstrate their understanding of “is-married-to” by realizing that alternative and semantically equivalent expressions of the relationship between Homer and Marge might be:

**Homer Simpson → is-married-to → Marge Simpson**
**Homer Simpson → is-the-husband-of → Marge Simpson**
**Marge Simpson → is-married-to → Homer Simpson**
**Marge Simpson → is-the-wife-of → Homer Simpson**

Going one step further, we could say that people understand the equivalence of these different expressions of the relationship because they have semantic and linguistic knowledge that relates some representation of “married,” “husband,” “wife,” and other words. None of that knowledge is visible in the expressions of the relationships so far, all of which specify concrete relationships about individ-
uals and not abstract relationships between resource classes or concepts. We have simply pushed the problem of what it means to understand the expressions into the mind of the person doing the understanding.

We can be more rigorous and define the words used in these expressions so they are “in the world” rather than just “in the mind” of the person understanding them. We can write definitions about these resource classes:

- The conventional or traditional marriage relationship is a consensual lifetime association between a husband and a wife, which is sanctioned by law and often by religious ceremonies;
- A husband is a male lifetime partner considered in relation to his wife; and
- A wife is a female lifetime partner considered in relation to her husband.

Definitions like these help a person learn and make some sense of the relationship expressions involving Homer and Marge. However, these definitions are not in a form that would enable someone to completely understand the Homer and Marge expressions; they rely on other undefined terms (consensual, law, lifetime, etc.), and they do not state the relationships among the concepts in the definitions. Furthermore, for a computer to understand the expressions, it needs a computer-processable representation of the relationships among words and meanings that makes every important semantic assumption and property precise and explicit. We will see what this takes starting in the next section.

5.3.1 Types of Semantic Relationships

In this discussion we will use “entity type,” “class,” “concept,” and “resource type” as synonyms. Entity type and class are conventional terms in data modeling and database design, “concept” is the conventional term in computational or cognitive modeling, and we use “resource type” when we discuss organizing systems. Similarly, we will use “entity occurrence,” instance, and “resource instance” when we refer to one thing rather than to a class or type of them.

There is no real consensus on how to categorize semantic relationships, but these three broad categories are reasonable for our purposes:

Inclusion

One entity type contains or is comprised of other entity types; often expressed using “is-a,” “is-a-type-of,” “is-part-of,” or “is-in” predicates.

Attribution

Asserting or assigning values to properties; the predicate depends on the property: “is-the-author-of,” “is-married-to,” “is-employed-by,” etc.
Possession

Asserting ownership or control of a resource; often expressed using a “has” predicate, such as “has-serial-number-plate.”

All of these are fundamental in organizing systems, both for describing and arranging resources themselves, and for describing the relationships among resources and resource descriptions.

5.3.1.1 Inclusion

There are three different types of inclusion relationships: class inclusion, meronymic inclusion, and topological inclusion. All three are commonly used in organizing systems.

Class Inclusion is the fundamental and familiar “is-a,” “is-a-type-of,” or “subset” relationship between two entity types or classes where one is contained in and thus more specific than the other more generic one.

Meat → is-a → Food

A set of interconnected class inclusion relationships creates a hierarchy, which is often called a taxonomy.

Meat → is-a → Food
Dairy Product → is-a → Food
Cereal → is-a → Food
Vegetable → is-a → Food
Beef → is-a → Meat
Pork → is-a → Meat
Chicken → is-a → Meat
Ground Beef → is-a → Beef
Steak → is-a → Beef
...

A visual depiction of the taxonomy makes the class hierarchy easier to perceive. See Figure 5.1, “A Partial Taxonomy of Food.”

Each level in a taxonomy subdivides the class above it into sub-classes, and each sub-class is further subdivided until the differences that remain among the members of each class no longer matter for the interactions the organizing system needs to support. We discuss the design of hierarchical organizing systems in §6.3, “Principles for Creating Categories.”

All of the examples in the current section have expressed abstract relationships between classes, in contrast to the earlier concrete ones about Homer and Marge, which expressed relationships between specific people. Homer and Marge are instances of classes like “married people,” “husbands,” and “wives.” When we make an assertion that a particular instance is a member of class, we
are **classifying** the instance. **Classification** is a class inclusion relationship between an instance and a class rather than between two classes. (We discuss Classification in detail in Chapter 7).

**Homer Simpson → is-a → Husband**

This is just the lowest level of the class hierarchy in which Homer is located at the very bottom; he is also a man, a human being, and a living organism (in cartoon land, at least).261 You might now remember the bibliographic class inclu-
sion hierarchy we discussed in §3.3.2, “Identity and Bibliographic Resources” (page 110); a specific physical item like your dog-eared copy of Macbeth is also a particular manifestation in some format or genre, and this expression is one of many for the abstract work.

Part-whole inclusion or meronymic inclusion is a second type of inclusion relationship. It is usually expressed using “is-part-of,” “is-partly,” or with other similar predicate expressions. Winston, Chaffin, and Herrmann identified six distinct types of part-whole relationships:262

- **Component-Object** is the relationship type when the part is a separate component that is arranged or assembled with other components to create a larger resource. In §3.1.1.1, “Resources with Parts,” we used as an example the component-object relationship between an engine and a car:

  **The Engine → is-part-of → the Car**
  
The components of this type of part-whole relationship need not be physical objects; “Germany is part of the European Union” expresses a component-object relationship. What matters is that the component is identifiable on its own as an integral entity and that the components follow some kind of patterned organization or structure when they form the whole. Together the parts form a composition, and the parts collectively form the whole. A car that lacks the engine part will not work.

- **Member-Collection** is the part-whole relationship type where “is-part-of” means “belongs-to,” a weaker kind of association than component-object because there is no assumption that the component has a specific role or function in the whole.

  **The Book → is-part-of → the Library**
  
The members of the collection exist independently of the whole; if the whole ceases to exist the individual resources still exist.

  **The Slice → is-part-of → the Pie**

- **Portion-Mass** is the relationship type when all the parts are similar to each other and to the whole, unlike either of the previous types where engines are not tires or cars, and books are not like record albums or libraries.

  **The Slice → is-part-of → the Pie**

- **Stuff-Object** relationships are most often expressed using “is-partly” or “is-made-of” and are distinguishable from component-object ones because the stuff cannot be separated from the object without altering its identity. The stuff is not a separate ingredient that is used to make the object; it is a constituent of it once it is made.

  **Wine → is-partly → Alcohol**

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• *Place-Area* relationships exist between areas and specific places or locations within them. Like members of collections, places have no particular functional contribution to the whole.

**The Everglades → are-part-of → Florida**

• *Feature-Activity* is a relationship type in which the components are stages, phases, or sub activities that take place over time. This relationship is similar to component-object in that the components in the whole are arranged according to a structure or pattern.

**Overtime → is-part-of → a Football Game**

A seventh type of part-whole relationship called *Phase-Activity* was proposed by Storey.263

• *Phase-Activity* is similar to *feature-activity* except that the phases do not make sense as standalone activities without the context provided by the activity as a whole.

**Paying → is-part-of → Shopping**

*Topological, Locative and Temporal Inclusion* is a third type of *inclusion relationship* between a container, area, or temporal duration and what it surrounds or contains. It is most often expressed using “is-in” as the relationship. However, the entity that is contained or surrounded is not a part of the including one, so this is not a *part-whole* relationship.

**The Vatican City → is-in → Italy**

**The meeting → is-in → the afternoon**

5.3.1.2 Attribution

In contrast to inclusion expressions that state relationships between resources, *attribution* relationships assert or assign values to properties for a particular resource. In Chapter 4 we used “attribute” to mean “an indivisible part of a resource description” and treated it as a synonym of “property.” We now need to be more precise and carefully distinguish between the type of the *attribute* and the *value* that it has. For example, the color of any object is an *attribute* of the object, and the value of that attribute might be “green.”

Some frameworks for semantic modeling define “attribute” very narrowly, restricting it to expressions with predicates with only one argument to assert properties of a single resource, distinguishing them from relationships between resources or resource types that require two arguments:264

**Martin the Gecko → is-small**

**Martin the Gecko → is-green**
However, it is always possible to express statements like these in ways that make them into relationships with two arguments:

**Martin** → **has-size** → **small**
**Martin** → **has-skin-color** → **green**

Dedre Gentner notes that this supposed distinction between one-predicate attributes and two-predicate relationships depends on context.\footnote{265} For example, small can be viewed as an attribute, \( X \rightarrow \text{is-small} \), or as a relationship between \( X \) and some standard or reference \( Y \), \( X \rightarrow \text{is-smaller-than} \rightarrow Y \).

Another somewhat tricky aspect of attribution relationships is that from a semantic perspective, there are often many different ways of expressing equivalent attribute values.

**Martin** → **has-size** → **6 inches**
**Martin** → **has size** → **152 mm**

These two statements express the idea that Martin is small. However, many implementations of attribution relationships treat the attribute values literally. This means that unless we can process these two statements using another relationship that expresses the conversion of inches to mm, the two statements could be interpreted as saying different things about Martin's size.

Finally, we note that we can express attribution relationships about other relationships, like the date a relationship was established. Homer and Marge Simpson's wedding anniversary is an attribute of their "is-married-to" relationship.

The semantic distinctions between attributes and other types of relationships are not strong ones, but they can be made clearer by implementation choices. For example, XML attributes are tightly coupled to a containing element, and their literal values are limited to atomic items of information. In contrast, inclusion relationships are expressed by literal containment of one XML element by another.

**5.3.1.3 Possession**

A third distinct category of semantic relationships is that of possession. Possession relationships can seem superficially like part-whole ones:

**Bob** → **has** → **a car**
**A car** → **has** → **wheels**

However, in the second of these relationships "has" is an elliptical form of "has as a part," expressing a component-object relationship rather than one of possession.

The concept of possession is especially important in institutional organizing systems, where questions of ownership, control, responsibility and transfers of
ownership, control, and responsibility can be fundamental parts of the interactions they support. However, possession is a complex notion, inherently connected to societal norms and conventions about property and kinship, making it messier than institutional processes might like. Possession relationships also imply duration or persistence, and are often difficult to distinguish from relationships based on habitual location or practice. Miller and Johnson-Laird illustrate the complex nature of possession relationships with this sentence, which expresses three different types of them:

- He owns an umbrella but she’s borrowed it, though she doesn’t have it with her.

5.3.2 Properties of Semantic Relationships

Semantic relationships can have numerous special properties that help explain what they mean and especially how they relate to each other. In the following sections we briefly explain those that are most important in systems for organizing resources and resource descriptions.

5.3.2.1 Symmetry

In most relationships the order in which the subject and object arguments are expressed is central to the meaning of the relationship. If X has a relationship with Y, it is usually not the case that Y has the same relationship with X. For example, because “is-parent-of” is an asymmetric relationship, only the first of these relationships holds:

**Homer Simpson → is-parent-of → Bart Simpson (TRUE)**

**Bart Simpson → is-parent-of → Homer Simpson (NOT TRUE)**

In contrast, some relationships are symmetric or bi-directional, and reversing the order of the arguments of the relationship predicate does not change the meaning. As we noted earlier, these two statements are semantically equivalent because “is-married-to” is symmetric:

**Homer Simpson → is-married-to → Marge Simpson**

**Marge Simpson → is-married-to → Homer Simpson**

We can represent the symmetric and bi-directional nature of these relationships by using a double-headed arrow:

**Homer Simpson = is-married-to = Marge Simpson**
5.3.2.2 Transitivity

*Transitivity* is another property that can apply to semantic relationships. When a relationship is transitive, if X and Y have a relationship, and Y and Z have the same relationship, then X also has the relationship with Z. Any relationship based on ordering is transitive, which includes numerical, alphabetic, and chronological ones as well as those that imply qualitative or quantitative measurement. Because “is-taller-than” is transitive:

**Homer Simpson → is-taller-than → Bart Simpson**

**Bart Simpson → is-taller-than → Maggie Simpson**

implies that:

**Homer Simpson → is-taller-than → Maggie Simpson**

Inclusion relationships are inherently transitive, because just as “is-taller-than” is an assertion about relative physical size, “is-a-type-of” and “is-part-of” are assertions about the relative sizes of abstract classes or categories.\(^\text{267}\)

Transitive relationships enable inferences about class membership or properties, and allow organizing systems to be more efficient in how they represent them since transitivity enables implicit relationships to be made explicit only when they are needed.

5.3.2.3 Equivalence

Any relationship that is both symmetric and transitive is an *equivalence relationship*; “is-equal-to” is obviously an equivalence relationship because if A=B then B=A and if A=B and B=C, then A=C. Other relationships can be equivalent without meaning “exactly equal,” as is the relationship of “is-congruent-to” for all triangles.

We often need to assert that a particular class or property has the same meaning as another class or property or that it is generally substitutable for it. We make this explicit with an equivalence relationship.

**Sister (English) = is-equivalent-to = Hermana (Spanish)**

5.3.2.4 Inverse

For asymmetric relationships, it is often useful to be explicit about the meaning of the relationship when the order of the arguments in the relationship is reversed. The resulting relationship is called the *inverse* or the converse of the first relationship. If an organizing system explicitly represents that:

**Is-child-of → is-the-inverse-of → Is-parent-of**
We can then conclude that:

\[ \text{Bart Simpson} \rightarrow \text{is-child-of} \rightarrow \text{Homer Simpson} \]

5.3.3 Ontologies

We now have described types and properties of semantic relationships in enough detail to return to the challenge we posed earlier: what information is required to fully understand relationships? This question has been asked and debated for decades and we will not pretend to answer it to any extent here. However, we can sketch out some of the basic parts of the solution.

Let us begin by recalling that a *taxonomy* captures a system of class inclusion relationships in some domain. But as we have seen, there are a great many kinds of relationships that are not about class inclusion. All of these other types of relationships represent knowledge about the domain that is potentially needed to understand statements about it and to make sense when more than one domain of resources or activities comes together.

For example, in the food domain whose partial taxonomy appears in §5.3.1, "Types of Semantic Relationships" (page 193), we can assert relationships about properties of classes and instances, express equivalences about them, and otherwise enhance the representation of the food domain to create a complex network of relationships. In addition, the food domain intersects with food preparation, agriculture, commerce, and many other domains. We also need to express the relationships among these domains to fully understand any of them.

\[
\begin{align*}
\text{Hamburger} & \rightarrow \text{is-equivalent-to} \rightarrow \text{Ground Beef} \\
\text{Hamburger} & \rightarrow \text{is-prepared-by} \rightarrow \text{Grilling} \\
\text{Grilling} & \rightarrow \text{is-a-type-of} \rightarrow \text{Food Preparation} \\
\text{Hamburger Sandwich} & \rightarrow \text{is-a-type-of} \rightarrow \text{Prepared Food} \\
\text{BigMac} & \rightarrow \text{is-a} \rightarrow \text{Hamburger Sandwich} \\
\text{A bun} & \rightarrow \text{is-part-of} \rightarrow \text{Hamburger Sandwich} \\
\text{A bun} & \rightarrow \text{is-partly} \rightarrow \text{flour} \\
\text{Temperature} & \rightarrow \text{is-a-measure-of} \rightarrow \text{Grilling} \\
\text{Rare} & \rightarrow \text{is-a} \rightarrow \text{State of Food Preparation} \\
\text{Well-done} & \rightarrow \text{is-a} \rightarrow \text{State of Food Preparation} \\
\text{Meat} & \rightarrow \text{is-preserved-by} \rightarrow \text{Freezing} \\
\text{Thawing} & \rightarrow \text{is-the-inverse-of} \rightarrow \text{Freezing} \\
\ldots
\end{align*}
\]

In this simple example we see that class inclusion relationships form a kind of backbone to which other kinds of relationships attach. We also see that there are many potentially relevant assertions that together represent the knowledge
that just about everyone knows about food and related domains. A network of relationships like these creates a resource that is called an ontology. A visual depiction of the ontology illustrates this idea that it has a taxonomy as its conceptual scaffold. See Figure 5.2, “A Partial Ontology of Food.”

There are numerous formats for expressing ontologies, but many of them have recently converged to or are based on the Web Ontology Language (OWL), the developed by the W3C. OWL ontologies use a formal logic-based language that
builds on RDF (§4.2.2.3, “Tagging of Web-Based Resources” (page 144)) to define resource classes and assign properties to them in rigorous ways, arrange them in a class hierarchy, establish their equivalence, and specify the properties of relationships.269

Ontologies are essential parts in some organizing systems, especially information-intensive ones where the scope and scale of the resources require an extensive and controlled description vocabulary (See §4.3, “The Process of Describing Resources” (page 148)). The most extensive ontology ever created is Cyc, born in 1984 as an artificial intelligence research project. Three decades later, the latest version of the Cyc ontology contains several hundred thousand terms and millions of assertions that interrelate them.270

5.4 The Lexical Perspective

The semantic perspective for analyzing relationships is the fundamental one, but it is intrinsically tied to the lexical one because a relationship is always expressed using words in a specific language. For example, we understand the relationships among the concepts or classes of “food,” “meat,” and “beef” by using the words “food,” “meat,” and “beef” to identify progressively smaller classes of edible things in a class hierarchy.

The connection between concept and words is not so simple. In the Simpson family example with which we began this chapter, we noted with “father” and “padre” that languages differ in the words they use to describe particular kinship relationships. Furthermore, we pointed out that cultures differ in which kinship relationships are conceptually distinct, so that languages like Chinese make distinctions about the relative ages of siblings that are not made in English.271 This is not to suggest that an English speaker cannot notice the difference between his older and younger sisters, only that this distinction is not lexicalized—captured in a single word—as it is in Chinese. This “missing word” in English from the perspective of Chinese is called a “lexical gap.”272

Earlier in this book we discussed the naming of resources (§3.4.2, “The Problems of Naming” (page 116)) and the design of a vocabulary for resource description (§4.3.1.3, “Scope, Scale, and Resource Description” (page 154)), and we explained how increasing the scope and scale of an organizing system made it essential to be more systematic and precise in assigning names and descriptions. We need to be sure that the terms we use to organize resources capture the similarities and differences between them well enough to support our interactions with them. After our discussion about semantic relationships in this chapter, we now have a clearer sense of what is required to bring like things together, keep different things separate, and to satisfy any other goals for the organizing system.
The LCC is highly enumerative, and along with the uniqueness principle, this creates distortions over time and sometimes requires contortions to incorporate new disciplines.\textsuperscript{417}

7.3.3 The BISAC Classification

A very different approach to bibliographic classification is represented in the \textit{Book Industry Standards Advisory Committee classification (BISAC)}. BISAC is developed by the Book Industry Study Group (BISG), a non-profit industry association that “develops, maintains, and promotes standards and best practices that enable the book industry to conduct business more efficiently.” The BISAC classification system is used by many of the major businesses within the North American book industry, including Amazon, Baker & Taylor, Barnes & Noble, Bookscan, Booksense, Bowker, Indigo, Ingram and most major publishers.\textsuperscript{418}

The BISAC classifications are used by publishers to suggest to booksellers how a book should be classified in physical and online bookstores. Because of its commercial and consumer focus, BISAC follows a principle of use warrant, and its categories are biased toward common language usage and popular culture. Some top-level BISAC categories, including Law, Medicine, Music, and Philosophy, are also top-level categories in the LCC. However, BISAC also has top-level categories for Comics & Graphic Novels. Cooking, Juvenile Fiction, Pets, and True Crime.

The differences between BISAC and the LCC are understandable because they are used for completely different purposes and generally have little need to come into contact. But this changed in 2004, when Google began its ambitious project to digitize the majority of the world’s books (See the Sidebar, “What Is a Library?” (page 21) in §1.3.1.2). Much to the dismay of many people in the library and academic community, Google initially classified books using BISAC rather than the LCC.\textsuperscript{419}

In addition, some new public libraries have adopted BISAC rather than the DDC because they feel the former makes the library friendlier to its users. Some librarians believe that their online catalogs need to be more like web search engines, so a less precise classification that uses more familiar category terms seems like a good choice.\textsuperscript{420}

7.4 Faceted Classification

We have noted several times that strictly enumerative classifications constrain how resources are assigned to categories and how the classification can evolve over time. \textbf{Faceted classifications} are an alternative that overcome some of these limitations. In a faceted classification system, each resource is described using properties from multiple facets, but an agent searching for resources does
not need to consider all of the properties (and consequently the facets) and does not need to consider them in a fixed order, which an enumerative hierarchical classification requires. Faceted classifications are especially useful in web user interfaces for online shopping or for browsing a large and heterogeneous museum collection. The process of considering facets in any order and ignoring those that are not relevant implies a dynamic organizational structure that makes selection both flexible and efficient. We can best illustrate these advantages with a shopping example in a domain that we are familiar with from §6.3.3, "Multiple Properties" (page 247).

If a department store offers shirts in various styles, colors, sizes, brands, and prices, shoppers might want to search and sort through them using properties from these facets in any order. However, in a physical store, this is not possible because the shirts must be arranged in actual locations in the store, with dress shirts in one area, work shirts in another, and so on.

Assume that the shirt store has shirts in four styles: dress shirts, work shirts, party shirts, and athletic shirts. The dress shirts come in white and blue, the work shirts in white and brown, and the party and athletic shirts come in white, blue, brown, and red. White dress shirts come in large and medium sizes.

Suppose we are looking for a white dress shirt in a large size. We can think of this desired shirt in two equivalent ways, either as a member of a category of "large white dress shirts" or a shirt with "dress," "white," and "large" values on style, color, and size facets. Because of the way the shirts are arranged in the physical store, our search process has to follow a hierarchical structure of categories. We go to the dress shirt section, find the white shirts, and then look within the white shirts for a large one. This process corresponds to the hierarchy shown in Figure 7.4, "Enumerative Classification with Style Facet Followed by Color Facet."

Although unlikely, a store might choose to organize its shirts by color. In our search for a "white dress shirt in a large size," if we consider the color first, because shirts come in four colors, there are four color categories to choose from. When we choose the white shirts, there is no category for work shirts because there are no work shirts that come in white. We then choose the dress shirts, and then finally find the large one. (Figure 7.5, "Enumerative Classification with Color Facet Followed by Style Facet.")

This department store example shows that for a physical organization, one property facet guides the localization of resources; all other facets are subordinated under the primary organizing property. In hierarchical enumerative classifications, this means that the primary organizing facet determines the primary form of access. The shirts are either organized by style and then color, or by color then style, which enforces an inflexible query strategy (either first by style or first by color).
In an online store, however, descriptions of the shirts are being searched and sorted instead of the real shirts, and different organizations are possible. When the shirts are described using a faceted classification system, we treat all facets independently, i.e. they can all be the primary facet.

We can enumerate all the properties needed to assign resources appropriately, but we create the categories (i.e. combination of properties from different facets) only if they are needed to sort resources with a particular combination of properties.

An additional aspect of the flexibility of faceted classification is that a facet can be left out of a resource description if it is not needed or appropriate. For example, because party shirts are often multi-colored with exotic patterns, it is not that useful to describe their color. Likewise, certain types of athletic shirts might be very loose-fitting, and as a result not be given a size description, but
Figure 7.5. Enumerative Classification with Color Facet Followed by Style Facet.

their color is important because it is tied to a particular team. Figure 7.6, “Faceted Classification.” shows how these two resource types can be classified with the faceted Shirt classification. Resource 1 describes a party shirt in medium; resource 2 describes an athletic shirt in blue without information about size.

A faceted classification scheme like that shown in Figure 7.6, “Faceted Classification.” eliminates the requirement for predetermining a combination and or-
### FACETED CLASSIFICATION

<table>
<thead>
<tr>
<th>COLOR</th>
<th>Blue</th>
<th>White</th>
<th>Brown</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>STYLE</td>
<td>Dress</td>
<td>Party</td>
<td>Athletic</td>
<td></td>
</tr>
<tr>
<td>SIZE</td>
<td>Large</td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource 1</td>
<td>Party</td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource 2</td>
<td>Blue</td>
<td>Athletic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7.6. Faceted Classification.**

Ordering of facets like those in Figure 7.4, “Enumerative Classification with Style Facet Followed by Color Facet.” and Figure 7.5, “Enumerative Classification with Color Facet Followed by Style Facet.” Instead, imagine a shirt store where you decide when you begin shopping which facets are important to you (“show me all the medium party shirts,” “show me the blue athletic shirts”) instead of having to adhere to whatever predetermined (pre-combined) enumerative classification the store came up with. In a digital organizing system, faceted classifi-
cation enables highly flexible access because prioritizing different facets can dynamically reorganize how the collection is presented.

7.4.1 Foundations for Faceted Classification

In library and information science texts it is common to credit the idea of faceted classification to S.R. Ranganathan, a Hindu mathematician working as a librarian. Ranganathan had an almost mystical motivation to classify everything in the universe with a single classification system and notation, considering it his dharma (the closest translation in English would be “fundamental duty” or “destiny”). Facing the limitations of Dewey’s system, where an item’s essence had to first be identified and then the item assigned to a category based on that essence, Ranganathan believed that all bibliographic resources could be organized around a more abstract variety of aspects.

In 1933 Ranganathan proposed that a set of five and only five facets applied to all knowledge:

**Personality**

The type of thing.

**Matter**

The constituent material of the thing.

**Energy**

The action or activity of the thing.

**Space**

Where the thing occurs.

**Time**

When the thing occurs.

This classification system is known as colon classification because the notation used for resource identifiers uses a colon to separate the values on each facet. These values come from tables of categories and subcategories, making the call number very compact. Colon classification is most commonly used in libraries in India.\(^{421}\)

For example, a book on “research in the cure of tuberculosis of lungs by x-ray conducted in India in 1950” has a Personality facet value of Medicine, a Matter facet value of Lungs with tuberculosis, an Energy facet value of Treatment using X-rays, a Space facet value of India, and a Time facet value of 1950. When the alphanumeric codes for these values are looked up in the classification tables, the composed call number is L.45;421:6;253:f.44'N5.\(^{422}\)

Ranganathan deserves credit for implementing the first faceted classification system, but people other than librarians generally credit the idea to Nicolas de
Condorcet, a French mathematician and philosopher. About 140 years before Ranganathan, Condorcet was concerned that “systems of classification that imposed a given interpretation upon Nature ... represented an insufferable obstacle to... scientific advance.” Condorcet thus proposed a flexible classification scheme for “arranging a large number of subjects in a system so that we may straightway grasp their relations, quickly perceive their combinations, and readily form new combinations.”

Condorcet’s system was based on five major facet categories, divided into 10 terms each, yielding $10^5$ or 100,000 combinations:

**Objects**
- domains of study.

**Methods**
- for studying objects and describing the knowledge gained.

**Points of view**
- for studying objects.

**Uses and utility**
- of knowledge.

**Ways**
- in which knowledge can be acquired.

Condorcet and Ranganathan proposed different facets, but both hoped that their five top-level facets would be sufficient for a universal classification system. People have generally rejected the idea of universal facets, but Ranganathan’s proposals continue to influence the development of the *Library of Congress Subject Headings* (LCSH).

Today faceted classification is most commonly used in narrow domains, each with its own specific facets. This makes intuitive sense because even if resources can be distinguished with a general classification, doing so requires lengthy notations, and it is much harder to add to a general classification than to a classification created specifically for a single subject area. We could probably figure out a way to describe shirts using the PMEST facets, but style, color, and size seem more natural.

### 7.4.2 Faceted Classification in Description

Elaine Svenonius defines facets as “groupings of terms obtained by the first division of a subject discipline into homogeneous or semantically cohesive categories.” The relationships between these facets results in a controlled vocabulary (§3.1.2) governing the resources we are organizing. From this controlled vocabulary we can generate many structured descriptions that are complex but
formally structured and enable us to describe things for which terms do not yet exist.

Getty's Art & Architecture Thesaurus (AAT) is a robust and widely used controlled vocabulary consisting of generic terms used to describe artifacts, objects, places and concepts in the domains of "art, architecture, and material culture." The AAT was developed in the mid-1980s and released as a book until 1997, when those maintaining it realized that the vocabulary was so large and changed so frequently that users would be better served by a dynamic online version that could change easily, rather than by a printed book bound to a publishing cycle.

AAT is a thesaurus with a faceted hierarchical structure. The AAT's facets are "conceptually organized in a scheme that proceeds from abstract concepts to concrete, physical artifacts:"

Associated Concepts
Concepts, philosophical and critical theory, and phenomena, such as "love" and "nihilism."

Physical Attributes
Material characteristics that can be measured and perceived, like "height" and "flexibility."

Styles and Periods
Artistic and architectural eras and stylistic groupings, such as "Renaissance" and "Dada."

Agents
Basically, people and the various groups and organizations with which they identify, whether based on physical, mental, socio-economic, or political characteristics—e.g., "stonemasons" or "socialists."

Activities
Actions, processes, and occurrences, such as "body painting" and "drawing." These are different from the "Objects" facet, which may also contain "body painting" but there in terms of the actual work itself, not the process of creation.

Materials
Concerned with the actual substance of which a work is made, like "metal" or "bleach." "Materials" differ from "Physical Attributes" in that the latter is more abstract than the former.

Objects
The largest facet, "Objects" contains the actual works, like "sandcastles" and "screen prints."
Within each facet is a strict hierarchical structure drilling down from broad term to very specific instance. For example, let's look at where we would find "patent leather" in the hierarchy (Figure 7.7. "Patent Leather" in the Art & Architecture Thesaurus.):426

Hierarchical Position

- Materials Facet
  - ...Materials (Hierarchy Name) (G)
  - ......materials (matter) (G)
  - ..........<materials by origin> (G)
  - ............<biological material> (G)
  - ...............animal material (G)
  - ................<processed animal material> (G)
  - ..................leather (G)
  - ....................<leather by process> (G)
  - .....................patent leather (G)

Figure 7.7. "Patent Leather" in the Art & Architecture Thesaurus.

We can see from this example how a particular instance may be described on a number of dimensions for the purpose of organizing the item and retrieving information about it. And by using a standard controlled vocabulary, catalogers and indexers make it easier for users to understand and adapt to the way things are organized for the purpose of finding them.

7.4.3 A Classification for Facets

There are four major types of facets.
Enumerative facets
Have mutually exclusive possible values. In our online shirt store, “Style” is an enumerative facet whose values are “dress,” “work,” “party,” and “athletic.”

Boolean facets
Take on one of two values, yes (true) or no (false) along some dimension or property. On a sportswear website, “Waterproof” would be a Boolean facet because an item of clothing is either waterproof or it is not.

Hierarchical facets
Organize resources by logical inclusion (§5.3.1.1). At Williams-Sonoma’s website, the top-level facet includes “Cookware,” “Cooks’ Tools,” and “Cutlery.” At wine.com the “Region” facet has values for “US,” “Old World,” and “New World,” each of which is further divided geographically. Also, taxonomic facets.

Spectrum facets
Assume a range of numerical values with a defined minimum and maximum. Price and date are common spectrum facets. The ranges are often modeled as mutually exclusive regions (potential price facet values might include “$0 - $49,” “$50 - $99,” and “$100 - $149”).

7.4.4 Designing a Faceted Classification System
It is important to be systematic and principled when designing a faceted classification. In some respects the process and design concerns overlap with those for describing resources, and much of the advice in §4.3, “The Process of Describing Resources” (page 148) is relevant here.

7.4.4.1 Design Process for Faceted Classification
We advocate a five step process for designing a faceted classification system.

1. Scoping.
Define the purposes of the classification (§4.3.2, “Determining the Purposes” (page 155), §7.2.1, “Classification Is Purposeful” (page 282)) and specify the collection of concepts or resources to be classified.

2. Choosing values for each facet.
For each facet, determine its logical type (§7.4.3, “A Classification for Facets” (page 301)) and possible values. Specify the order of the values for each facet so that they make sense to users; useful orderings are alphabetical, chronological, procedural, size, most popular to least popular, simple to complex, and geographical or topological.
3. **Identifying facets.**

Analyze and describe a representative sample of resource instances to identify properties or dimensions as candidate facets (See §4.3.3, "Identifying Properties" (page 160)).

4. **Designing the facet hierarchy and grammar.**

Examine the relationships between the facets to create subfacets if necessary. Determine how the facets will be combined to generate the classifications.

5. **Validation, Iteration and Refinement.**

Test the classification on new instances, and revise the facets, facet values, and facet grammar as needed.

7.4.4.2 Design Principles and Pragmatics

Here is some more specific advice about selecting and designing facets and facet values:

**Orthogonality**

Facets should be independent dimensions, so a resource can have values of all of them while only having one value on each of them. In an online kitchen store, one facet might be “Product” and another might be “Brand.” A particular item might be classified as a “Saucerpan” in the “Product” facet and as “Calphalon” in the “Brand” one. Other saucepans might have other brands, and other Calphalon products might not be saucepans, because Product and Brand are orthogonal.

**Semantic Balance**

Top-level facets should be the properties that best differentiate the resources in the classification domain. The values should be of equal semantic scope so that resources are distributed among the subcategories. Subfacets of “Cookware” like “Sauciers and Saucepans” and “Roasters and Brasiers” are semantically balanced as they are both named and grouped by cooking activity.\(^{431}\)

**Coverage**

The values of a facet should be able of classifying all instances within the intended scope.

**Scalability**

Facet values must accommodate potential additions to the set of instances. Including an “Other” value is an easy way to ensure that a facet is flexible and hospitable to new instances, but it not desirable if all new instances will be assigned that value.