Introduction to Caché

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Caché Version 2018.1 2019-09-20
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About This Book

This book describes Caché, a high-performance database that combines an object database, high-performance SQL, and powerful multidimensional data access.

This book addresses the following topics:

- What Is Caché?
- The Caché Database Engine
- Objects, SQL, and the Unified Data Architecture

For a detailed outline, see the table of contents.

Also see the following documents:

- *Caché Programming Orientation Guide*
- *Using Caché Objects*
- *Using Caché ObjectScript*
- *Using Caché SQL*
- *The Caché System Administration Guide*
- *The Caché Security Administration Guide*
- *InterSystems Programming Tools Index*

For general information, see *Using InterSystems Documentation*.

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What Is Caché?

Welcome to Caché, a high-performance object database.

This book provides an overview of the major features of Caché.

For more details on a specific topic, refer to one of the other books available from the online documentation home page. In addition, Caché includes a number of online tutorials on various development and system administration topics.

1.1 A Unique Architecture

Caché derives much of its power from its unique architecture. At the core, the Caché database engine provides the complete set of services — including data storage, concurrency management, transactions, and process management — needed to build complex database management systems. You can think of the Caché engine as a powerful database toolkit. Using this toolkit, Caché implements a complete object and relational database management system.

The benefits of this architecture are manifold:

- The object and relational database systems talk directly to the database engine for extremely efficient operation; there is no object-relational middleware or SQL-to-object bridge technology.
- The logical separation of the database from its physical implementation makes it possible to radically reconfigure application deployments with no change to application logic.
- Because the database engine interface is open, you can make direct use of its features where needed. This can range from building your own customized database management system to adding targeted optimizations to performance critical applications.
- A platform for the future: The Caché architecture makes future database engine enhancements possible without impact on existing applications. For example, Caché v4.1 introduced a brand-new physical data structure, with dramatically improved scalability and performance, that not only required no change to existing applications but also required no change to the Caché object or relational systems. As new technologies emerge, Caché can add support for them as native, high-performance components with little impact to existing applications.

1.2 A High-performance Object Database — with Relational Access

Caché is designed to transcend the limitations of the relational model while providing an evolutionary upgrade path for the thousands of existing relational database applications as well as support for the many SQL-based reporting tools on the market.

In addition to being a high-performance object database, Caché is also a full-featured relational database. All the data within a Caché database is available as true relational tables and can be queried and modified using standard SQL via ODBC, JDBC, or object methods. Because of the power of the underlying Caché database engine, we believe that Caché is the fastest, most reliable, and most scalable relational database available today.

Additionally, Caché offers features that go beyond the limits of relational databases, while still supporting a standard relational view of data. These features include:

- The ability to model data as objects (each with an automatically created and synchronized native relational representation) while eliminating both the impedance mismatch between databases and object-oriented application environments as well as reducing the complexity of relational modeling
- A simpler, object-based concurrency model
- User-defined data types
- The ability to take advantage of methods and inheritance, including polymorphism, within the database engine
- Object-extensions for SQL to handle object identity and relationships
- The ability to intermix SQL and object-based access within a single application, using each for what they are best suited
- Control over the physical layout and clustering used to store data in order to ensure the maximum performance for applications

While most databases with both object and relational access provide one form of access on top of the other, the SQL and object aspects of Caché both go directly to the data — so that users enjoy the performance benefit of either approach.

For information, see the first several chapters of the *Caché Programming Orientation Guide*.

1.3 A Broad Tool Set

Caché offers a broad set of tools, which include:

- ObjectScript, the language in which most of Caché is written.
- Native implementations of SQL, MultiValue, and Basic.
- A well-developed, built-in security model
- A suite of technologies and tools that provide rapid development for database and web applications
- Native, object-based XML and web services support
- Device support (such as files, TCP/IP, printers)
- Automatic interoperability via Java, JDBC, ActiveX, .NET, C++, ODBC, XML, SOAP, Perl, Python, and more

- Support for common Internet protocols: POP3, SMTP, MIME, FTP, and so on
- A reusable user portal for your end users
- Support for analyzing unstructured data
- Support for Business Intelligence (BI)
- Built-in testing facilities

For a comprehensive list of tools, see the table of contents of the *InterSystems Programming Tools Index*.

1.4 Caché in Action

Caché is used around the world for a wide variety of applications ranging from single-user embedded systems, to enterprise-wide multiserver installations with tens of thousands of concurrent users, to statewide and nationwide applications.

A small sample of applications built with Caché includes:

- As the application platform for a large healthcare network running hundreds of patient-critical applications. The network includes a set of Caché systems acting as data and application servers and has over 30,000 client machines.
- As the data server for a Java-based enterprise messaging system for large financial institutions. Caché was chosen both for its performance and its ability to carry out customized tasks not possible within a traditional relational database.
- As an SQL-based OLTP (online transaction processing) system for a large government organization with over 1400 concurrent users. Caché was a drop-in (no application changes) replacement when other relational products failed to perform.
- As an object database and web application framework for an online educational system used by a leading technical university. Caché was chosen for its rapid development (the application had to be built in three months), its object capabilities, as well as its ability to scale without application reworking.
- As an object database used to track real-time position and velocity of professional athletes during a world championship. Caché was chosen for its performance (compared with the leading object and relational databases) and its native C++ interface.
- As a distributed SQL data engine for a major web site with millions of users. This site uses a set of cost-effective Linux-based servers and uses the Caché distributed data management to provide a scalable, personalized site with no middleware or web caching infrastructure. The hardware costs of this system (four off-the-shelf Linux machines) were less than 10% of those quoted by a "leading database for Internet applications."

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2

The Caché Database Engine

At the heart of Caché lies the Caché Database Engine. The database engine is highly optimized for performance, concurrency, scalability, and reliability. There is a high degree of platform-specific optimization to attain maximum performance on each supported platform.

Caché is a full-featured database system; it includes all the features needed for running mission-critical applications (including journaling, backup and recovery, and system administration tools). To help reduce operating costs, Caché is designed to require significantly less database administration than other database products. The majority of deployed Caché systems have no database administrators.

The major features of the database engine are described in the following sections.

2.1 Transactional Multidimensional Storage

All data within Caché is stored within sparse, multidimensional arrays. Unlike the multidimensional arrays used by typical OLAP (online analytic processing) products, Caché supports transaction processing operations (inserts, updates, locking, transactions) within its multidimensional structures. Also, unlike most OLAP engines, these multidimensional structures are not limited in size to available memory. Instead, Caché includes a sophisticated, efficient data cache.

Because Caché data is of inherently variable length and is stored in sparse arrays, Caché often requires less than half of the space needed by a relational database. In addition to reducing disk requirements, compact data storage enhances performance because more data can be read or written with a single I/O operation, and data can be cached more efficiently.

Multidimensional arrays give applications a great degree of flexibility in how they store their data. For example, a set of closely related objects, say an Invoice object and its corresponding LineItem objects, can easily be configured so that the LineItem objects are physically clustered with a Invoice object for highly efficient access.

The flexibility of transactional multidimensional storage gives Caché a significant advantage over the two–dimensional structure used by traditional relational databases: it is this flexibility that allows Caché to be a high-performance SQL, object, and XML database without compromise. It also means that Caché applications are better prepared for future changes in technology.

2.1.1 Mapping

Using a unique feature known as *mapping*, you can specify how the data within one or more arrays (or parts of arrays) is mapped to a physical database file. Such mapping is a database administration task and requires no change to class/table definitions or application logic. Moreover, mapping can be done within a specific sparse array; you can map one range of values to one physical location while mapping another to another file, disk drive, or even to another database server. This makes it possible to reconfigure Caché applications (such as for scaling) with little effort.

2.2 Process Management

A process is an instance of a Caché virtual machine running on a Caché server. A typical Caché server can run thousands of simultaneous processes depending on hardware and operating system. Each process has direct, efficient access to the multidimensional storage system.

The Caché virtual machine executes instructions (called *P-code*) that are highly optimized for the database, I/O, and logic operations typically required by transaction processing and data warehousing applications.

2.3 Lock Management

To support concurrent database access, Caché includes a powerful Lock Management System.

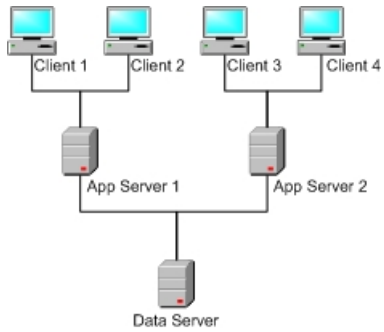
In systems with thousands of users, reducing conflicts between competing processes is critical to providing high performance. One of the biggest conflicts is between transactions wishing to access the same data. Caché offers the following features to alleviate such conflicts:

- Atomic Operations — To eliminate typical performance hot spots, Caché supports a number of atomic operations, that is with no need for application level locks. An example is the ability to atomically allocate unique values for object/row identity (a common bottleneck in relational applications).
- Logical Locks — Caché does not lock entire pages of data while performing updates. Because most transactions require frequent access or changes to small quantities of data, Caché supports granular logical locks that can be taken out on a per-object (row) basis.
- Distributed Locks — In distributed database configurations (see the next topic), the system automatically supports distributed locks.

2.4 Distributed Data Management

One of the most powerful features of Caché is its ability to link servers together to form a distributed data network. In such a network, machines that primarily serve data are known as Data Servers while those that mainly host processes, but little to no data, are known as Application Servers.

Figure 2–1: Enterprise Cache Protocol



Servers can share data (as well as locks) using the Caché Enterprise Cache Protocol (ECP). ECP is effective because data is transported in packages. When information is requested across the network, the reply data package includes the desired

data as well as additional related data. The natural data relationships inherent to objects and the Caché multidimensional data model make it possible to identify and include information that is related to the originally requested data. This "associated" information is cached locally either at the client or on the application server. Usually, subsequent requests for data can be satisfied from a local cache, thus avoiding additional trips across the network. If the client changes any data, only the updates are propagated back to the database server.

ECP makes it possible for applications to support a wide variety of runtime configurations including multi-tier and peer-to-peer.

2.5 Journal Management

To provide database integrity and reliability, Caché includes a number of journaling subsystems that keep track of physical and logical database updates. The journal management technology is also used to provide transaction support (a journal is used to perform transaction rollback operations) as well as database shadowing (a journal is used to synchronize a shadow server with a primary data server). As with the rest of the system, Caché lets you configure its journaling system to meet your needs.

2.6 Database Portability

Caché runs on, and is optimized for, a wide variety of hardware platforms and operating systems, as documented in the online *InterSystems Supported Platforms* document for this release.

You can easily port applications developed with Caché as well as data from one platform to another. This can be as easy as installing Caché on the new platform and moving the database files to new system. When moving between some systems, you may need to run an in-place data conversion utility (to convert one endian representation to another).

2.7 Deployment Options

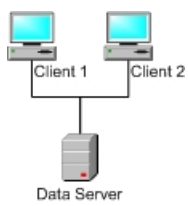
Caché supports a variety of different runtime configurations giving you maximum flexibility when you deploy your applications. You can switch between different deployment options by changing Caché system settings; typically there is no need to change your application logic.

Some basic deployment options are listed below.

2.7.1 Basic Client/Server Configuration

In the simplest client/server configuration, a single Caché data server services a number of clients (from one to many thousands, depending on the application and platform).

Figure 2–2: Client/Server Configuration



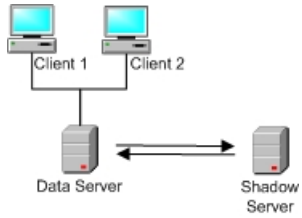
The client systems can be any of the following:

- Stand-alone desktop systems running a client application that connects via a client/server protocol (such as ODBC, ActiveX, JDBC, Java).
- Web server processes talking to Caché via Zen, CSP (Caché Server Pages), SOAP, or some other connectivity option (such as ODBC, JDBC). Each web server process may then service a number of browser-based or machine-to-machine sessions.
- Middleware processes (such as an Enterprise Java Bean application server) that connect to Caché via ODBC, JDBC, etc.
- Devices, such as terminals or lab equipment, that connect to Caché using one of many supported protocols (including TELNET and TCP/IP).
- Some combination of the above.

2.7.2 Shadow Server Configuration

The shadow server configuration builds upon the basic client/server setup by adding one or more shadow servers. Each shadow server synchronizes itself with the data within the main data server by connecting to and monitoring its journal.

Figure 2–3: Shadow Server Configuration

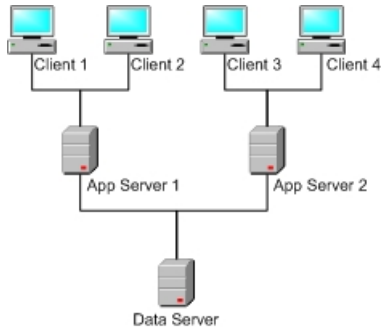


Shadow servers are typically used to service ad hoc queries, large reports, and batch processes to limit their impact on the main transaction system. They can also be used to provide failover systems.

2.7.3 Multi-Tier Configuration

The multi-tier configuration uses the Caché distributed database technology — the Enterprise Cache Protocol (ECP) — to make it possible for a greater number of clients to connect to the system.

Figure 2–4: Multi-tier Configuration



In the simplest multi-tier setup, one or more Caché systems, acting as application servers, are placed between the central data server and the various client systems. In this case the application servers do not store any data, instead they host processes that perform work for the benefit of the client, off-loading the CPU of the data server. This type of configuration scales best for applications that exhibit good "locality of reference," that is most transactions involve reasonably related data so

that locking across application servers is limited. Such applications, as well as those with a fair amount of read access (like most typical web applications), work extremely well in this model.

More complex configurations, with multiple data servers as well as data stored on application server machines, are also possible.

Typically applications use the multi-tier configuration for scaling as well as for providing high-availability (with applications servers serving as hot standby systems).

3

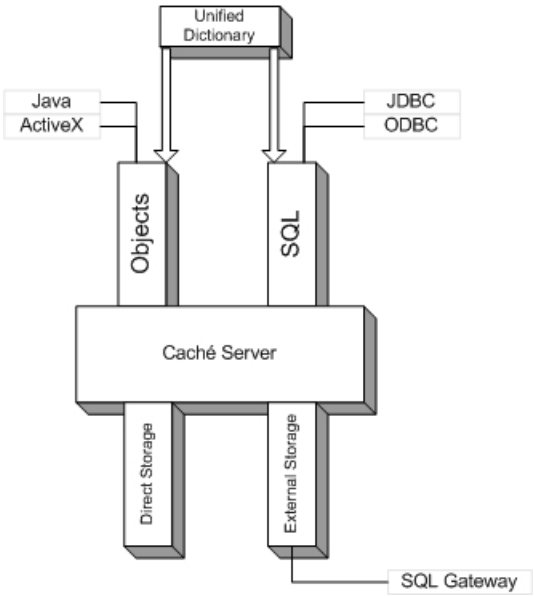
Objects, SQL, and the Unified Data Architecture

A powerful and unique feature of Caché is its unique Unified Data Architecture that provides simultaneous, high-performance object and relational access to data stored within Caché.

3.1 Unified Data Dictionary

Within Caché, you can model your application components as objects. Objects are organized by classes which define the data (properties) and behavior (methods) of the object.

Figure 3–1: Unified Data Architecture



The meta-information, or definition, of each class is stored within a common repository referred to as the Caché class dictionary. The class dictionary is itself an object database, stored within Caché, whose contents can be accessed using objects. The class dictionary, by means of a class compiler, defines the storage structure needed by persistent objects and converts class definitions into parallel sets of executable code that provide both the object and relational access to this storage

structure. By means of this architecture, the object and relational code paths are efficient and automatically synchronized with one another.

Class definitions can be added to the class dictionary in a number of ways:

- Interactively, using the Studio development environment.
- Relationally, using DDL. Caché accepts standard SQL DDL statements and automatically creates corresponding class and table definitions.
- Textually, using XML. Caché supports an external, XML representation of class definitions. Typically this is used for source code management, deployment, automatic code generation, and interoperation with other tools.
- Programmatically, using objects. Using the Caché set of class definition objects, you can create programs that communicate directly with the class dictionary and create new classes at application runtime.
- Using an XML Schema Wizard, included within Studio, that can create class definitions from most XML schema files.

3.1.1 Flexible Storage

The Caché object model differs from those of programming languages in that in addition to properties and methods, you can specify storage-related behavior such as indices, constraints, and storage structure.

The storage structure used by persistent objects is independent of the logical definition of a class and is quite flexible: developers can use the default structures provided by the class compiler or they can tune the structures for specific cases.

3.2 Objects

Caché includes a full-featured, next-generation object database specifically designed to meet the needs of complex, transaction oriented applications. The Caché object model includes the following features:

- Classes — You can define classes that represent the state (data) and behavior (code) of your application components. Classes are used to create instances of objects as both runtime components and as items stored within the database.
- Properties — Classes can include properties, which specify the data associated with each object instance. Properties can be simple literals (such as strings or integers), user-defined types (defined using data type classes), complex (or embedded) objects, collections, or references to other objects.
- Relationships — Classes can define how instances of objects are related to one another. The system automatically provides navigational methods for relationships as well as referential integrity within the database.
- Methods — Classes can define behavior by means of methods: executable code associated with an object. Object methods run within a Caché server process (though they can be invoked from a remote client). Object methods can be scripted using ObjectScript, SQL, or they can be generated using method generators, which are code that automatically creates customized methods according to user-defined rules.
- Object persistence — Persistent objects have the ability to automatically store and retrieve themselves to a database. The persistence support includes complete database functionality including automatic transaction management, concurrency control, index maintenance, and data validation. Persistent objects are automatically visible through SQL queries.
- Inheritance — By deriving new classes from existing ones, you can reuse previously written code as well as create specialized versions of classes.
- Polymorphism — Caché supports complete object polymorphism. This means that applications can use a well-defined interface (a set of methods and properties provided by a superclass) and the system will automatically invoke the correct

interface implementation based on the type of each object. This makes it much easier to develop flexible database applications.

- Swizzling (also known as "lazy loading") — Caché automatically swizzles (brings into memory from disk) any related persistent objects when they are referenced from other objects. This greatly simplifies working with complex data models.

The Caché object functionality is not a separate part of Caché; it is a central part of Caché programming and is fully integrated with relational access described elsewhere. However, for those who are interested specifically in object-oriented programming, the manual Using Caché Objects discusses Caché programming from this point of view.

3.2.1 Defining Classes

The simplest and most common way to define classes within Caché is to use the Studio development environment. The Studio lets you define classes either using a simple text format within a syntax-coloring editor or by using a graphical point-and-click interface. These two views are interchangeable and are automatically synchronized.

Here is the definition of an extremely simple persistent object, Component, as seen within Studio:

```
Class MyApp.Component Extends %Persistent
{
Property TheName As %String;
Property TheValue As %Integer;
}
```

This class is defined as a persistent class (that is, it can store itself within a database). In this case, the Caché-provided, %Persistent class (system class names start with a "%" character to distinguish them from application classes) provides all the needed persistence code via inheritance. The class belongs to the package, "MyApp". Packages group related classes together and greatly simplify development of large applications. The class defines two properties: TheName, which has a string value, and TheValue, which has an integer value.

From within ObjectScript code, such as within a method, you can use this object syntax to manipulate instances of Component object:

```
 // Create a new component
 Set component = ##class(MyApp.Component).%New()
 Set component.TheName = "Widget"
 Set component.TheValue = 22

 // Save the new Component to the database
 Do component.%Save()
```

Using Basic, you can define a method to manipulate instances of the Component object:

```
' Create a new component
component = New Component()
component.TheName = "Widget"
component.TheValue = 22

' Save the new Component to the database
component.%Save()
```

At this point, a new instance of Component is stored within the database with a system-assigned unique object identifier. You can later retrieve this object by opening it (using its object identifier):

```
' Open an instance and double its value:
component = OpenId Component(id)

component.TheValue = component.TheValue * 2
component.%Save()
```

You can perform the exact same operations using native Java, C++, or other Caché client bindings. The class compiler can generate, and synchronize, any additional code required to access objects externally. For example, if you are using Caché

with Java, you can specify that the class compiler automatically generate and maintain Java proxy classes that provide remote access to persistent database classes. Within a Java program you can use this object naturally:

```
// Get an instance of Component from the database
component = (MyApp.Component)MyApp.Component._open(database, new Id(id));

// Inspect some properties of this object
System.out.println("Name: " + component.getTheName());
System.out.println("Value: " + component.getTheValue());
```

3.3 SQL

Caché SQL is a full-featured relational database engine that is fully integrated with the Caché object technology. In addition to standard SQL-92 features, Caché SQL offers:

- Support for streams (known in SQL as Binary Large Objects, or BLOBS).
- Support for stored procedures (implemented as object methods).
- A set of object-based extensions.
- User-definable data types.
- Support for Transactional Bitmap Indices.

  Bitmap indices, typically used in large data warehousing and OLAP systems, offer the ability to perform high-speed searches based on complex combinations of conditions. Such bitmap indices cannot be updated in real-time, however and are typically updated as a batch process. Caché SQL supports bitmap indices that offer high-performance searching power combined with no loss in insert/update performance. This gives transaction processing applications the ability to perform data warehouse-style queries and gives data warehouse applications the ability to perform real-time updates. For more information, refer to the "Bitmap Indices" content in the Caché SQL Optimization Guide.

3.3.1 The Object/Relational Connection

All components within the Caché dictionary are defined as classes. The class compiler automatically projects persistent classes as relational tables. For every object feature, there is a corresponding relational equivalent, as illustrated in the following table:

Table 3–1: Relational View of Object Features

Object Feature	Relational Equivalent
Package	Schema
Class	Table
Object instance	Row within a table
Property	Column
Relationship	Foreign key
Embedded object	Multiple columns
Method	Stored procedure
Index	Index

When Caché loads SQL DDL (Data Definition Language) statements, it uses the inverse of this projection to create classes that correspond to relational tables.

To demonstrate the object-to-relational projection, consider a simple example. Here is the definition of a simple, persistent Person class (part of a package called "MyApp") containing two properties, Name and Home:

```
Class MyApp.Person Extends %Persistent
{
Property Name As %String(MAXLEN=100);
Property Home As Address;
}
```

The Person class gets its persistent behavior from the %Persistent superclass provided with Caché. The Name property is defined as a simple String of up to 100 characters.

The Home property illustrates the use of complex, user-defined data types, in this case the Address class, which is defined as:

```
Class MyApp.Address Extends %SerialObject
{
Property City As %String;
Property State As %String;
}
```

The Address class is derived from the %SerialObject superclass. This class provides the ability to serialize itself (convert itself to a single-string representation) and embed itself within another containing class (as with the Person class).

When viewed via SQL, the Person class has the following structure:

Table 3–2: SQL View of the Person class: SELECT * FROM Person

ID	Name	Home_City	Home_State
1	Smith,John	Cambridge	MA
2	Doe,Jane	Dallas	TX

Note that the object identifier is visible as a column. In addition, the fields of the embedded Address object are projected as separate fields. These fields are given the synthetic names Home_City and Home_State and behave exactly as if they were defined as two individual fields.

3.3.2 Inheritance and SQL

Inheritance is an important feature within object-based systems and is completely lacking within relational databases. Caché SQL makes it possible to use the power of inheritance using standard relational constructs. For example, we can derive a new Employee class from the Person class used in the previous example:

```
Class MyApp.Employee Extends Person
{
Property Salary As %Integer(MINVAL=0,MAXVAL=100000);
}
```

This new class extends the Person class by adding an additional property, Salary.

When viewed via SQL, the Employee class has the following structure:

Table 3–3: SQL View of the Employee class: SELECT * FROM Employee

ID	Name	Home_City	Home_State	Salary
3	Divad, Gino	Irvine	CA	22000

Notice that all of the inherited properties are available as columns. Also note that only rows that are actual instances of Employee are included. If we again ask for all Person instances:

Table 3–4: Revised SQL View of the Person class: SELECT * FROM Person

ID	Name	Home_City	Home_State
1	Smith,John	Cambridge	MA
2	Doe,Jane	Dallas	TX
3	Divad, Gino	Irvine	CA

In this case, we see that all the rows are returned because every Employee is defined to be an instance of Person. In this case, however, only the properties defined by Person are displayed.

3.3.3 Object Extensions to SQL

To make it easier to use SQL within object applications, Caché includes a number of object extensions to SQL.

One of the most interesting of these extensions is ability to follow object references using the reference ("–>") operator. For example, suppose you have a Vendor class that refers to two other classes: Contact and Region. You can refer to properties of the related classes using the reference operator:

```
SELECT ID,Name,ContactInfo->Name
FROM Vendor
WHERE Vendor->Region->Name = 'Antarctica'
```

Of course, you can also express the same query using SQL JOIN syntax. The advantage of the reference operator syntax is that it is succinct and easy to understand at a glance.