O'REILLY®

# Snowflake The Definitive Guide

## Architecting, Designing, and Deploying on the Snowflake Data Cloud

Early Release

RAW & UNEDITED

Joyce Kay Avila

# Snowflake: The Definitive Guide

## *Architecting, Designing, and Deploying on the Snowflake Data Cloud*

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

*Joyce Kay Avila*

Beijing • Boston • Farnham • Sebastopol • Tokyo O'REILLY®

**Snowflake: The Definitive Guide**
by Joyce Kay Avila



Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (*http://oreilly.com*). For more information, contact our corporate/institutional sales department: 800-998-9938 or *corporate@oreilly.com*.

**Acquisitions Editor:** Jessica Haberman
**Development Editor:** Michele Cronin
**Production Editor:**
**Copyeditor:**
**Proofreader:**

**Indexer:**
**Interior Designer:** David Futato
**Cover Designer:** Karen Montgomery
**Illustrator:**

September 2022: First Edition

**Revision History for the Early Release**

2021-08-04: First Release
2021-09-13: Second Release
2021-10-20: Third Release
2021-12-17: Fourth Release
2022-02-08: Fifth Release
2022-03-17: Sixth Release
2022-04-13: Seventh Release

See *http://oreilly.com/catalog/errata.csp?isbn=9781098103828* for release details.



978-1-098-10382-8

[LSI]

# Table of Contents

CHAPTER 1

# Creating and Managing Snowflake Architecture

## A Note for Early Release Readers

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

This will be the 2nd chapter of the final book.

If you have comments about how we might improve the content and/or examples in this book, or if you notice missing material within this chapter, please reach out to the editor at *mcronin@oreilly.com*.

In the last decade, computer data storage and computer performance had to evolve. Teams, both large and small, near or far apart, often needed access to the same data at the same time. Having access to that data and the ability to generate actionable insights quickly is now an absolutely must. The sheer amount and complexity of today's data platforms, including data warehouses, had to evolve into incredibly data-intensive applications. Yet, as we'll discover in the next section, simply making modifications to existing data platform architectures did not solve the scalability problem. Then, Snowflake burst onto the scene with a unique architecture.

Snowflake is an evolutionary modern data platform that solved the scalability problem. Compared to traditional cloud data platform architectures, Snowflake enables data storage and processing that is significantly faster and easier to use and is much more affordable. Snowflake's Data Cloud provides users with a unique experience by

combining a new SQL query engine with an innovative architecture that was designed and built from the ground up, specifically for the cloud.

# Traditional Data Platform Architectures

In this section, we'll briefly review some traditional data platform architectures and how they were designed in an attempt to improve scalability. Scalability is the ability of a system to handle an increasing amount of work. We'll also discuss the limitations of these architectures and we will discover what makes the Snowflake Data Cloud architecture so unique. Afterward, we will learn about each of the three different Snowflake architecture layers in detail: Cloud Services Layer, Query Processing (Virtual Warehouse) Compute Layer, and the Centralized (Hybrid-Columnar) Database Storage Layer.

## Shared-Disk (Scalable) Architecture

The shared-disk architecture was an early scaling approach designed to keep data stored in a central storage location, accessible from multiple database cluster nodes (Figure 1-1). The data accessed by each of the cluster nodes is consistently available because all data modifications are written to the shared disk. This architecture is a traditional database design and is known for the simplicity of its data management. While the approach is simple in theory, it requires complex on-disk locking mechanisms to ensure data consistency which, in turn, causes bottlenecks. Data concurrency, allowing many users to affect multiple transactions within a database, is also a major problem and adding more compute nodes only compounds the problem in a shared-disk architecture. Therefore, the true scalability of this architecture is limited.

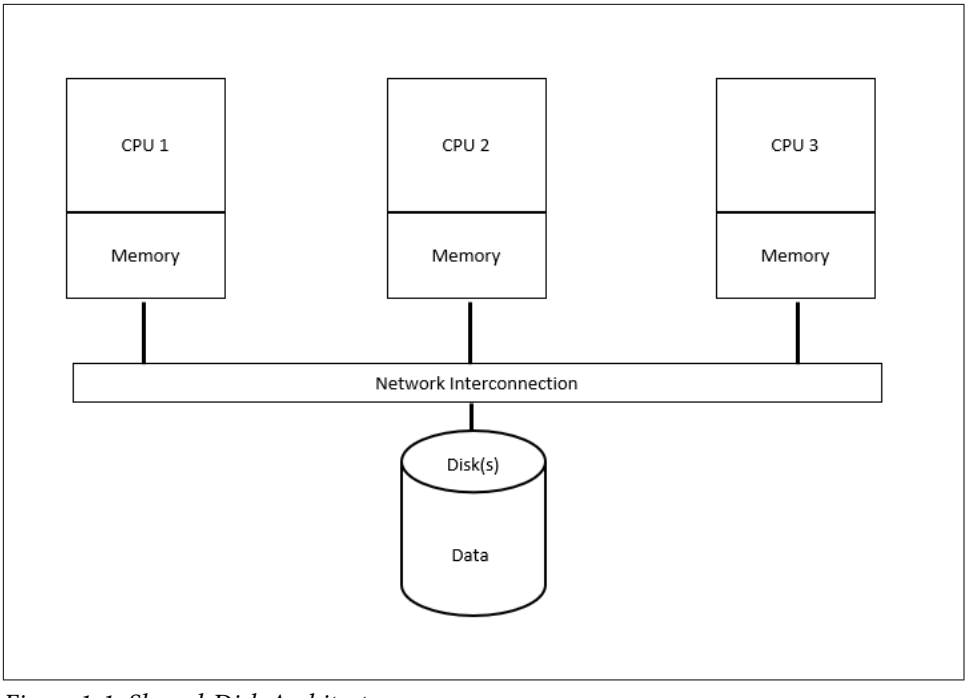



*Figure 1-1. Shared-Disk Architecture*

Oracle RAC is an example of shared disk architecture.

## Shared-Nothing (Scalable) Architecture

The shared-nothing architecture, in which storage and compute is scaled together (Figure 1-2), was designed in response to the bottleneck created by the shared-disk architecture. This evolution in architecture was made possible because storage had become relatively inexpensive. However, distributed cluster nodes along with the associated disk storage, CPU, and memory, requires data to be shuffled between nodes, which adds overhead. Depending on how the data is distributed across the nodes will determine the extent of the additional overhead. Striking the right balance between storage and compute is especially difficult. Even when it is possible to resize a cluster, it takes time to do so. Thus, organizations often overprovision shared-nothing resources, which results in unused, unneeded resources.

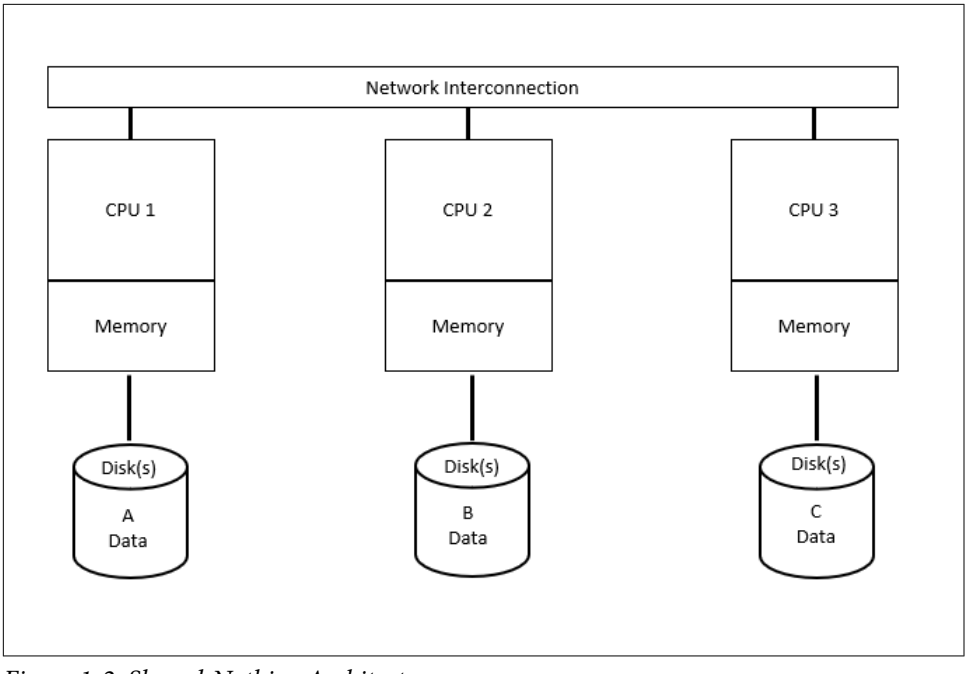



*Figure 1-2. Shared-Nothing Architecture*

Shared nothing architecture is also known as Massively Parallel Processing (MPP). Examples of a Shared Nothing architecture include IBM DB2, Vertica, and Pivotal Greenplum.

## NoSQL Alternatives

Most NOSQL solutions rely on shared-nothing architecture; thus, they have many of the same limitations. However, the benefit of NoSQL solutions is that they can store non-relational data without first requiring transformation of the data. Additionally, most NoSQL systems don't require schemas. NoSQL, a term that implies "Not Only SQL" rather than "NO to SQL", is a good choice for storing e-mail, web links, social media posts and tweets, road maps, and spatial data.

There are four types of NoSQL databases: Document Stores, Key-Value (KV) Stores, Column Family Data Stores or Wide Column Data Stores, and Graph Databases.

Document-based NoSQL databases such as MongoDB store data in JSON objects where each document has key-value pair like structures. Key-value databases such as DynamoDB are especially useful for capturing customer behavior in a specific session. Cassandra is an example of a column-based database where large numbers of dynamic columns are logically grouped into column families. Graph-based databases, such as Neo4j and Amazon Neptune, work well for recommendation engines and

social networks where they're able to help find patterns or relationships among data points.

A major limitation of NoSQL stores is that they perform poorly when doing calculations involving many records, such as aggregations, window functions, and arbitrary ordering. Thus, NoSQL stores can be great when you need to quickly create, read, update and delete (CRUD) individual entries in a table but aren't recommended for adhoc analysis. Additionally, NoSQL alternative solutions require specialized skill sets and they aren't compatible with most SQL-based tools.

The NoSQL solutions, however, are not database warehouse replacements. While NoSQL alternatives can be useful for data scientists, they do not perform well for analytics.

## Snowflake Architecture

Even the improved traditional data platforms, especially those that were implemented on-premise, couldn't adequately address modern data problems or solve the long-standing scalability issue. The Snowflake team made the decision to take a unique approach. Rather than trying to incrementally improve or transform existing software architectures, the Snowflake team's approach was to build an entirely new modern data platform, just for the cloud, that allows multiple users to concurrently share live data.

The unique Snowflake design physically separates but logically integrates storage and compute along with providing services such as security and management. As we explore the many unique Snowflake features throughout the upcoming chapters, you'll be able to see for yourself why the Snowflake architecture is the only architecture that can enable the Data Cloud.

The Snowflake hybrid-model architecture is comprised of three layers (Figure 1-3) known as the cloud services layer, the compute layer, and the data storage layer. Each of these layers, along with the three Snowflake caches, are discussed in more detail in the following sections.

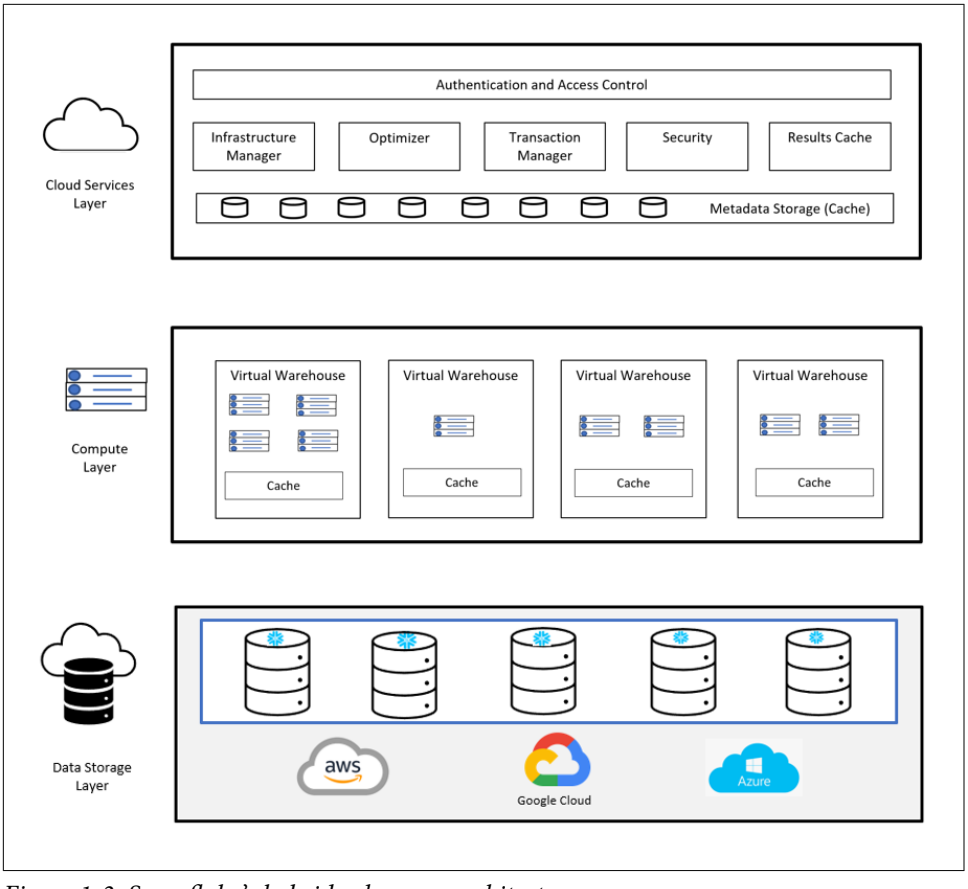



*Figure 1-3. Snowflake's hybrid columnar architecture*

Snowflake's processing engine is native SQL and, as we will see in later chapters, Snowflake is also able to handle semi-structured and unstructured data.

## Managing the Cloud Services Layer

All interactions with data in a Snowflake instance begin in the cloud services layer, also called the global services layer (Figure 1-4). The Snowflake cloud services layer is a collection of services that coordinate activities such as authentication, access control and encryption. It also includes management functions for handling infrastructure and metadata, as well as performing query parsing and optimization, among other features. This global services layer is sometimes referred to as the Snowflake "brain" because all the various service layer components work together to handle user requests that begin from the time a user requests to log in.

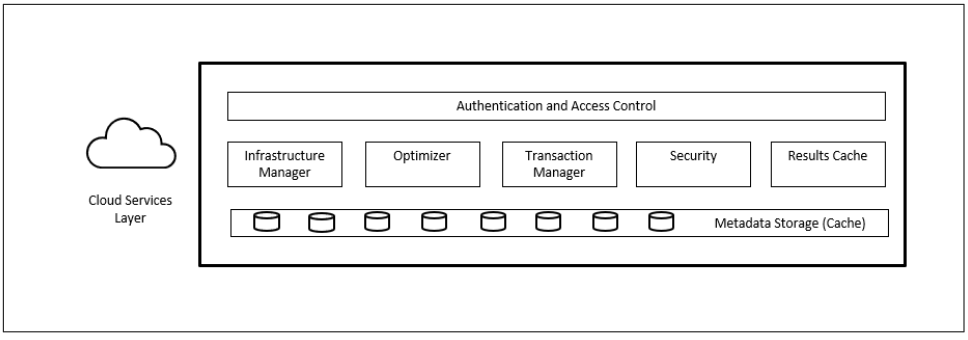



*Figure 1-4. Snowflake Cloud Services Layer*

Each time a user requests to log in, their request is handled by the services layer. When a user submits a Snowflake query, the SQL query will be sent to the cloud services layer optimizer before being sent to the compute layer for processing. The service layer is what enables the SQL client interface for Data Definition Language (DDL) and Data Manipulation Language (DML) operations on data.

The cloud services layer manages data security including the security for data sharing. The Snowflake cloud services layer runs across multiple availability zones in each cloud provider region and holds the results cache, a cached copy of the executed query results. The metadata required for query optimization or data filtering are also stored in the cloud services layer.

Just like the other Snowflake layers, the cloud services layer will scale independently of the other layers. The scaling of the cloud services layer is an automated process that cannot be directly manipulated by the Snowflake end user.

## Billing for the Cloud Services Layer

Most cloud services consumption is already incorporated into Snowflake pricing. However, when cloud services layer usage exceeds 10% of compute usage (calculated daily), they are billed at the normal credit price. Note that daily compute credit usage is calculated daily in UTC time zone.

All queries use a small amount of cloud services resources. Data Definition Language operations are metadata operations and, as such, they use only cloud services. Keeping both facts in mind, we should evaluate some situations where we know the cost will be higher for cloud services to consider whether the benefits will be worth the increased costs.

Increased usage of the cloud services layer will likely occur when using several simple queries, especially queries accessing session information or using session variables.

Increased usage also occurs when using large complex queries with many joins. Single row inserts, rather than bulk or batch loading, will also result in higher cloud services consumption. Finally, you'll consume only cloud services resources if you use Information_Schema commands or certain metadata-only commands such as the "Show" command. If you are experiencing higher than expected costs for cloud services, you may want to investigate these situations. Be sure to also investigate any partner tools, including those using the JDBC driver, as there could be opportunities for improvement from these third-party tools.

Even though the cloud services cost for a particular use case is high, sometimes it makes sense either economically and/or strategically to incur those costs. For example, taking advantage of the result cache for queries, especially for large or complex queries, will mean zero compute cost for that query. Thoughtful choices about the right frequency and granularity for DDL commands, especially for use cases such as cloning, help to better balance the costs between cloud services consumption and warehouse costs to achieve an overall lower cost

## Query Processing (Virtual Warehouse) Compute Layer

A Snowflake compute cluster, most often referred to simply as a "virtual warehouse," is a dynamic cluster of compute resources consisting of CPU memory and temporary storage. Creating virtual warehouses in Snowflake makes use of the compute clusters, virtual machines in the cloud, which are provisioned behind the scenes. Snowflake doesn't publish the exact server in use at any given time; it could change as the cloud providers modify their services. The Snowflake compute resources are created and deployed on-demand anytime to a Snowflake user, such as yourself, for whom the process is transparent.

A running virtual warehouse is required for most SQL queries and all DML operations, including loading and unloading data into tables, as well as updating rows in tables. Some SQL queries can be executed without requiring a virtual warehouse and we'll soon see examples of that when we discuss the query results cache later in the chapter.

Snowflake's unique architecture allows for separation of storage and compute which means any virtual warehouse can access the same data as another, without any contention or impact on performance of the other warehouses.

No virtual warehouse has an impact on any other virtual warehouse because each Snowflake virtual warehouse operates independently and does not share compute resources with other virtual warehouses (Figure 1-5).

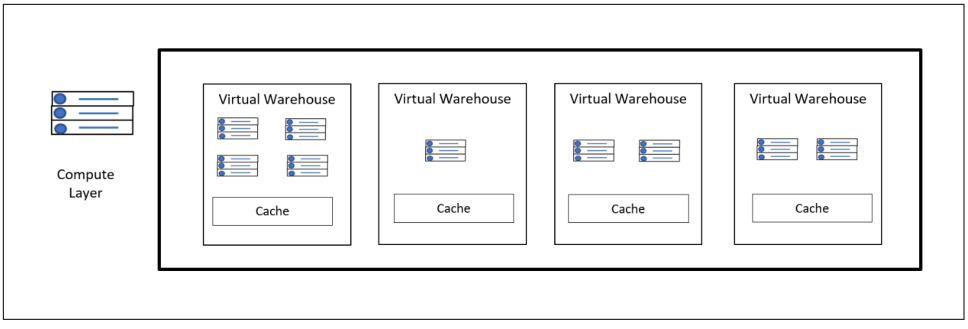



*Figure 1-5. Snowflake Compute (Virtual Warehouse) Layer*

A virtual warehouse is always consuming credits when it is running in a session. However, Snowflake virtual warehouses can be started and stopped at any time and they can be resized at any time, even while running. Snowflake supports two different ways to scale warehouses. Virtual warehouses can be scaled up by resizing a warehouse and can be scaled out by adding clusters to a warehouse. It is possible to use one or both scaling methods at a time.

Unlike the Snowflake cloud services layer and the data storage layer, the Snowflake virtual warehouse layer (Figure 1-5) is not a multi-tenant architecture. Snowflake pre-determines the CPU, memory, and SSD configurations for each node in a virtual warehouse (Figure 2-6). While these definitions are subject to change, they are consistent in configuration across all three cloud providers.

## Virtual Warehouse Size

A Snowflake compute cluster is defined by its size with size corresponding to the number of servers in the virtual warehouse cluster. For each virtual warehouse size increase, the number of servers per cluster increases by a factor of 2 up to size 4X-Large (Figure 2-6). Beyond 4X-Large, a different approach is used to determine the number of servers per cluster. However, the credits per hour does still increase by a factor of 2 for these extremely large virtual warehouses.

*Table 1-1. Snowflake Virtual Warehouse Sizes and associated number of servers per cluster*

| X-Small | Small | Medium | Large | X-Large | 2X-Large | 3X-Large | 4X- Large |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 8 | 16 | 32 | 64 | 128 |

Virtual Warehouse resizing to a larger size, also known as scaling up, is most often undertaken to improve query performance and handle large workloads. This will be discussed in more detail in the next section.

Because Snowflake utilizes per second billing, it can often be cost effective to run larger warehouses because you are able to suspend virtual warehouses when they aren't being used. The exception is when you are running a lot of small or very basic queries on large warehouse sizes. There won't likely be any benefit from adding the additional resources regardless of the number of concurrent queries.

## Scaling Up a Virtual Warehouse to Process Large Data Volumes and Complex Queries

In a perfect world (i.e., simple workload, exact same per test), you'd pay the same total cost for using an XS virtual warehouse as using a 4XL virtual warehouse. The only difference would be a decrease in the time to completion. In reality, though, it isn't quite that simple. Many factors affect the performance of a virtual warehouse. The number of concurrent queries, the number of tables being queried, and the size and composition of the data are a few things that should be considered when sizing a Snowflake virtual warehouse.

Sizing appropriately matters. A lack of resources, due to the virtual warehouse being too small, could result in taking too long to complete the query. There could be a negative impact if the query is too small and the virtual warehouse too large.

Resizing a Snowflake virtual warehouse is a manual process and can be done even while queries are running because a virtual warehouse does not have to be stopped or suspended to be resized. However, when a Snowflake virtual warehouse is resized, only subsequent queries will make use of the new size. Any queries already running will finish running while any queued queries will run on the newly sized virtual warehouse. Scaling a virtual warehouse UP will increase the number of servers (Figure 1-6). An example would be from MEDIUM to LARGE. Scaling a virtual warehouse DOWN will decrease the number of servers.

It is recommended that you experiment with different types of queries and different virtual warehouse sizes to determine the best way to manage your virtual warehouses effectively and efficiently. The queries should be of a certain size and complexity that you would typically expect to complete within no more than 5 to 10 minutes. Additionally, it is recommended that you start small and increase in size as you experience. It is easier to identify an undersized virtual warehouse than an under-utilized one.

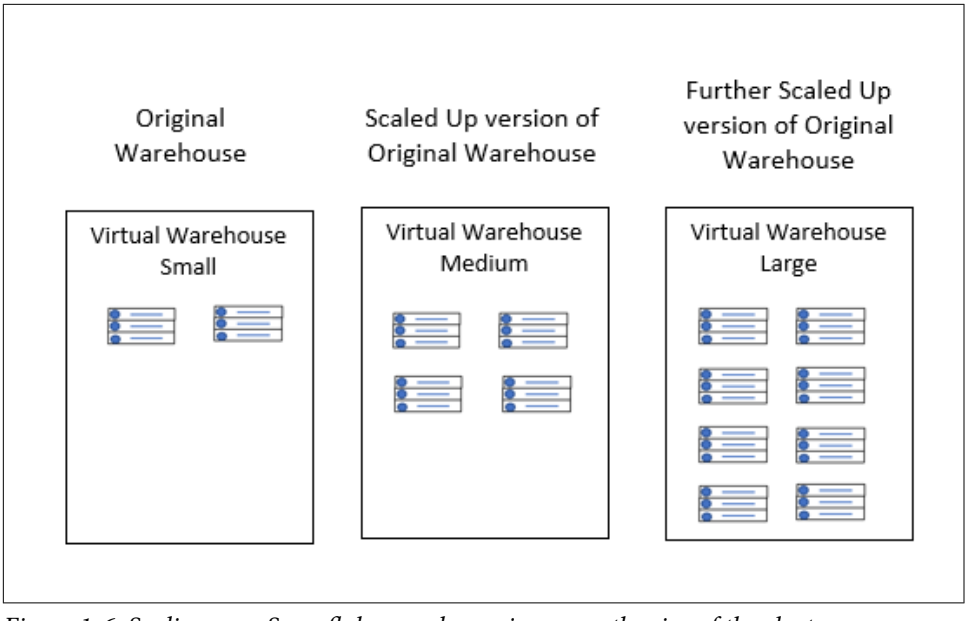



*Figure 1-6. Scaling up a Snowflake warehouse increases the size of the cluster*

In practice, you'd create a new Original virtual warehouse with the size being defined as small, as shown in Figure 1-7.

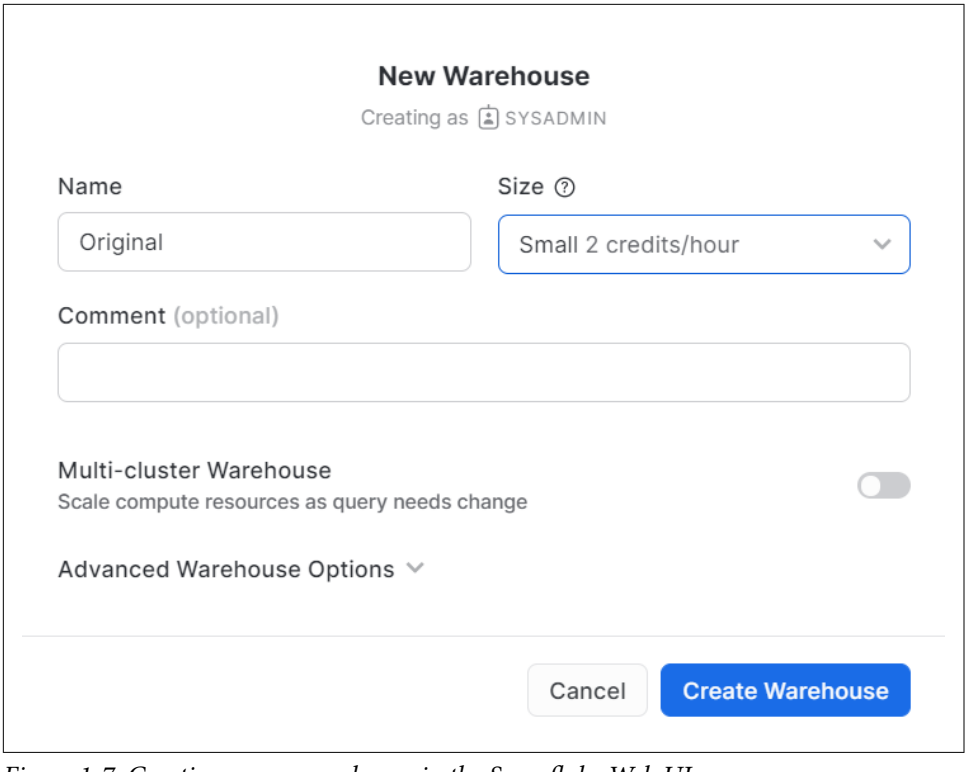



*Figure 1-7. Creating a new warehouse in the Snowflake Web UI*

Then, to scale up the Original virtual warehouse, you would edit the virtual warehouse properties to increase the cluster size to medium (Figure 1-8).

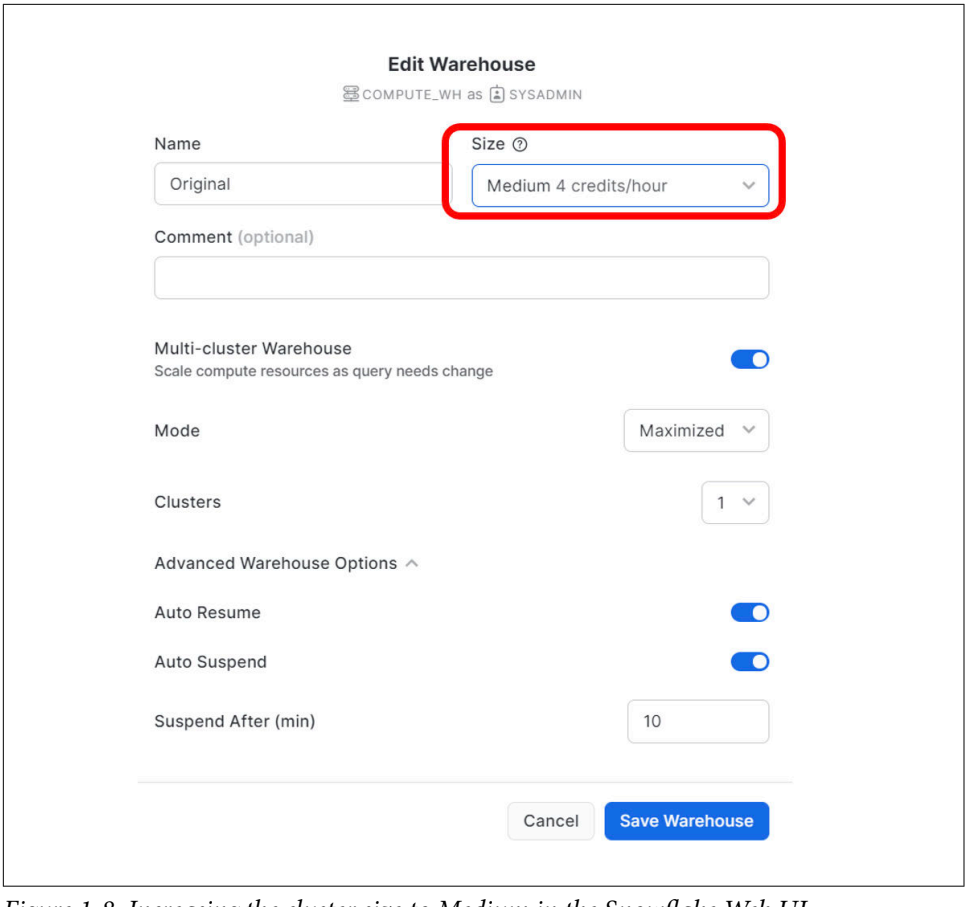



*Figure 1-8. Increasing the cluster size to Medium in the Snowflake Web UI*

Larger virtual warehouses do not necessarily result in better performance for query processing or data loading.

Query processing, in terms of query complexity, is a consideration for choosing a virtual warehouse size because the time it takes for a server to execute a complex query will likely be greater than running a simple query. The amount of data to be loaded or unloaded can greatly affect performance. We'll be diving into data loading and unloading in Chapter 6 and reviewing ways to improve performance in Chapter 9.

## Scaling Out with Multi-Cluster Warehouses to Maximize Concurrency

A multi-cluster warehouse operates in much the same way as a single-cluster warehouse. The goal is to find the right balance where the Snowflake system will perform optimally in terms of size and number of clusters. From the previous section, we learned that when there was a queuing problem due to very long-running SQL queries or when there was a large data volume to be loaded or unloaded then scaling up could result in increased performance since the queries could run faster.

If a concurrency problem is due to many users, or connections, then scaling up will not adequately address the problem. Instead, we'll need to scale out by adding clusters (Figure 1-9), going from a MIN value of 1 to a MAX value of 3, for example. Multi-cluster warehouses can be set to automatically scale if the number of users and/or queries tend to fluctuate.

Multi-cluster warehouses are available on the Enterprise, Business Critical, and Virtual Private Snowflake Editions.

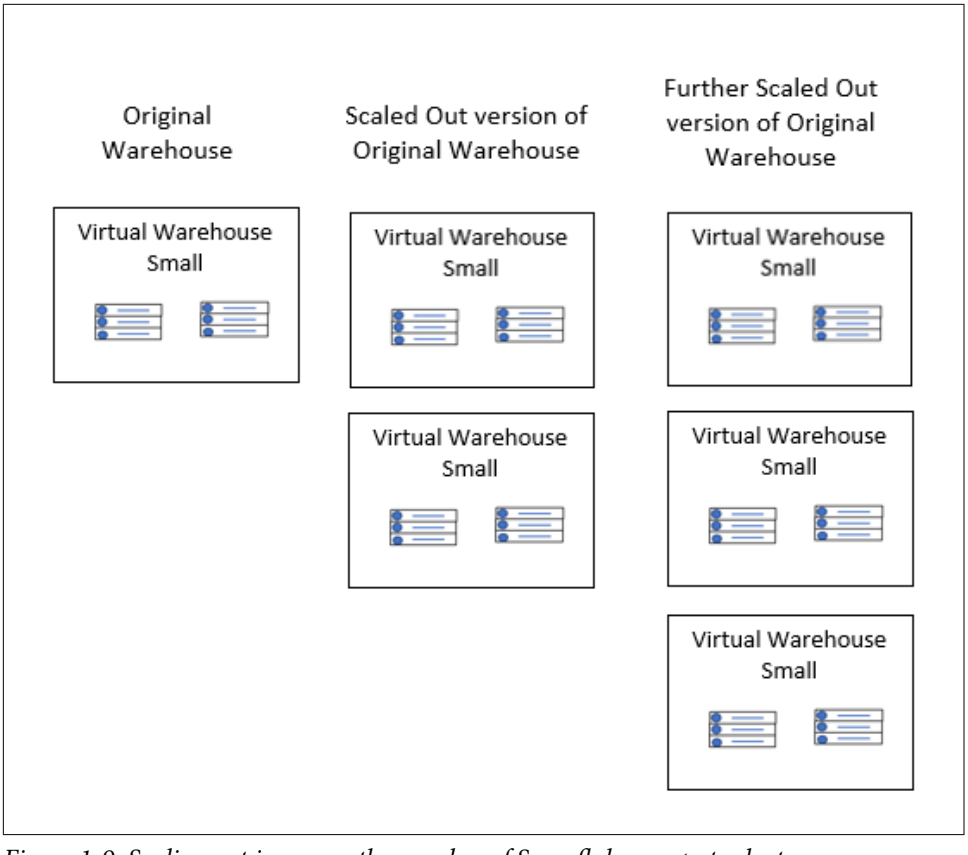



*Figure 1-9. Scaling out increases the number of Snowflake compute clusters*

Just like single cluster warehouses, multi-cluster warehouses can be created through the web interface or by using SQL for Snowflake instances. Unlike single cluster warehouses where sizing is a manual process, scaling in or out for multi-cluster warehouses is an automated process. An example of how you can edit a Snowflake virtual warehouse to have a minimum of one small cluster and a maximum of three small clusters can be seen in Figure 1-10.

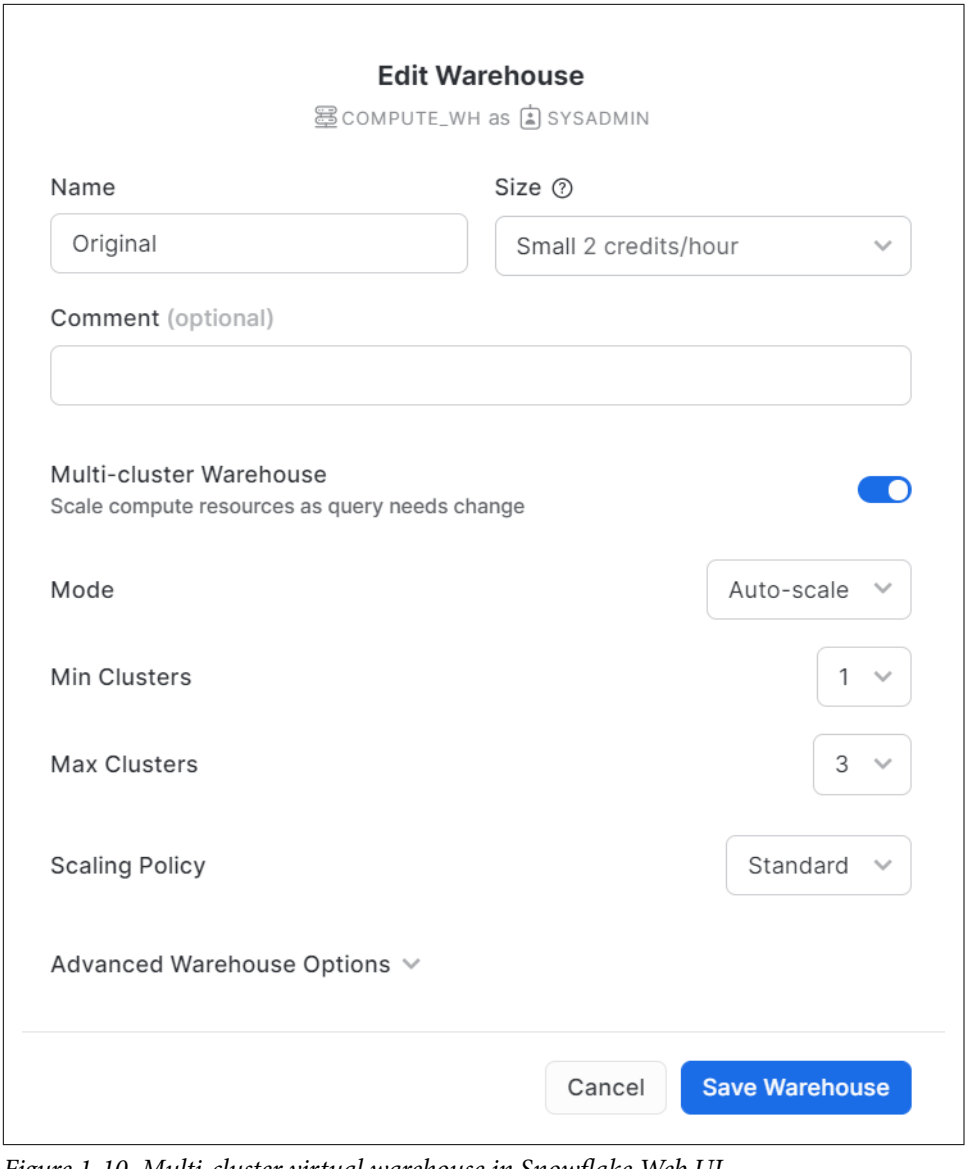



*Figure 1-10. Multi-cluster virtual warehouse in Snowflake Web UI*

The two different types of modes that can selected for a multi-cluster warehouse are *auto-scale* and *maximized*. The Snowflake scaling policy, designed to help control the usage credits in the auto-scale mode, can be set to *standard* or *economy*.

Whenever a multi-cluster warehouse is configured with the scaling policy set as standard, the first warehouse immediately starts when a query is queued, or the Snowflake system detects that there is one more query than the currently-running clusters

can execute. Each successive warehouse starts 20 seconds after the prior warehouse has started.

If a multi-cluster warehouse is configured with the scaling policy set as economy, a warehouse starts only if the Snowflake system estimates the query load can keep the warehouse busy for at least six minutes. The goal of the economy scaling policy is to conserve credits by keeping warehouses fully loaded. As a result, queries may end up being queued and could take longer to complete.

It is recommended to set the MAXIMUM value as high as possible, while being aware of the associated costs. For example, if you set the MAXIMUM at 10, keep in mind you could experience a tenfold compute cost for the length of time all 10 clusters are running. A multi-cluster warehouse is "maximized" when the MINIMUM is greater than 1 and both the MINIMUM and MAXIMUM values are equal. We'll see an example of that in the next section.

Compute can be scaled up, down, in, or out. In all cases, there is no effect on storage used.

## Creating and Using Virtual Warehouses

Commands for virtual warehouses can be executed in the Web UI or within a worksheet by using SQL. We'll first take a look at creating and managing virtual warehouses with SQL. Next, we'll take a look at the Web UI functionality for virtual warehouses.

Auto-suspend and auto-resume are two options available when creating a Snowflake virtual warehouse. Auto-suspend is the number of seconds that the virtual warehouse will wait if no queries need to be executed before going offline. Auto-resume will restart the virtual warehouse once there is an operation that requires compute resources.

The following SQL script will create a medium virtual warehouse, with four clusters, that will automatically suspend after 5 minutes. The virtual warehouse will immediately resume when queries are executed.

```
USE ROLE SYSADMIN;
CREATE WAREHOUSE WH_CH2 WITH WAREHOUSE_SIZE = MEDIUM Auto_suspend = 300 Auto_resume
= true Initially_suspended = true;
```

Unless the Snowflake virtual warehouse is created initially in a suspended state, the initial creation of a Snowflake virtual warehouse could take time to provision compute resources.

Earlier, we discussed how we can scale virtual warehouses up or down and that doing so is a manual process. In order to scale up or down, i.e., change the size of a virtual warehouse, we will use the "Alter" command.

```
USE ROLE SYSADMIN;
ALTER WAREHOUSE WH_CH2
SET
    WAREHOUSE_SIZE = LARGE;
```

Any SQL statements executed in this workbook after creating this virtual warehouse will run on that virtual warehouse. If you prefer to use a certain warehouse to execute a script instead, then you can specify that warehouse in the worksheet.

```
USE WAREHOUSE WH_CH2;
```

Alternatively, you can update the warehouse field in the context menu located on the left by selecting Compute then Warehouse (Figure 1-11).

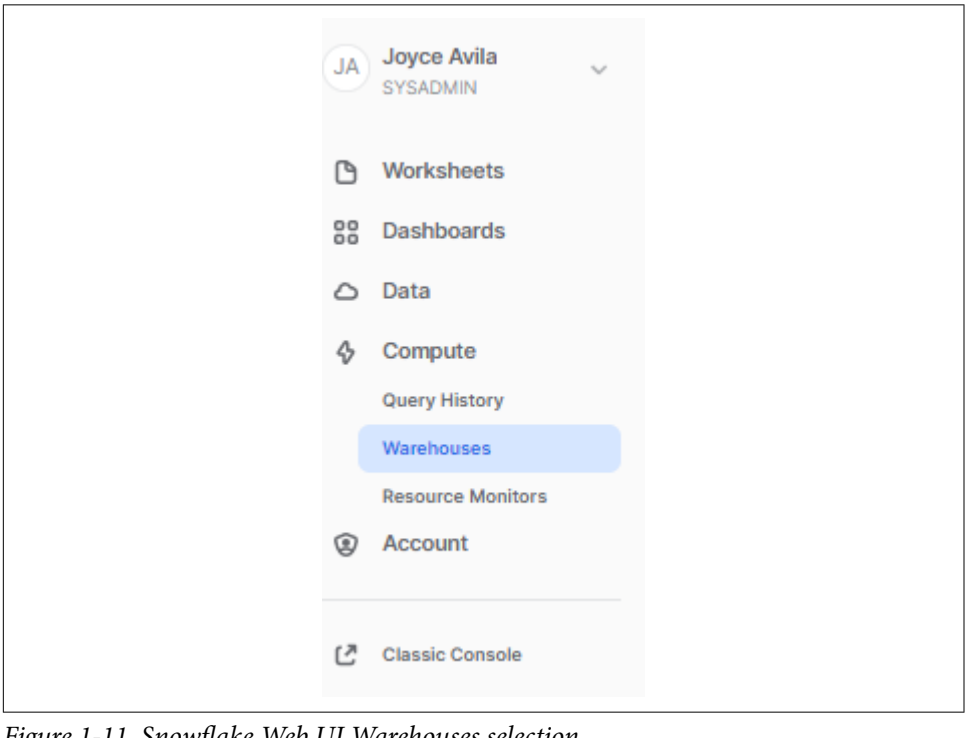



*Figure 1-11. Snowflake Web UI Warehouses selection*

Once you select Warehouses from the sub-menu, you'll see the list of available virtual warehouses, their status, size, clusters, and more information (Figure 1-12).

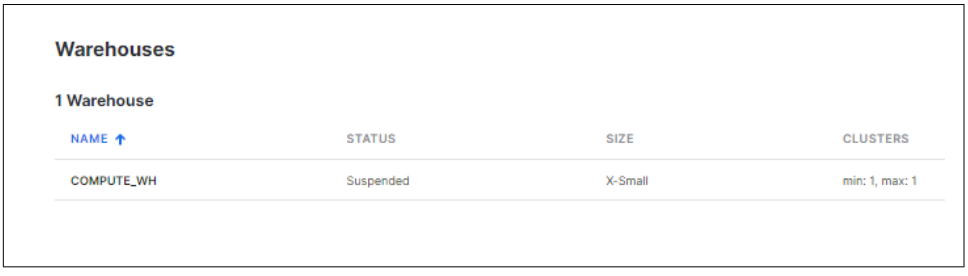



*Figure 1-12. Snowflake Web UI detail in the Warehouses selection*

Look to the far right, click on the ellipses and then select edit (Figure 1-13)

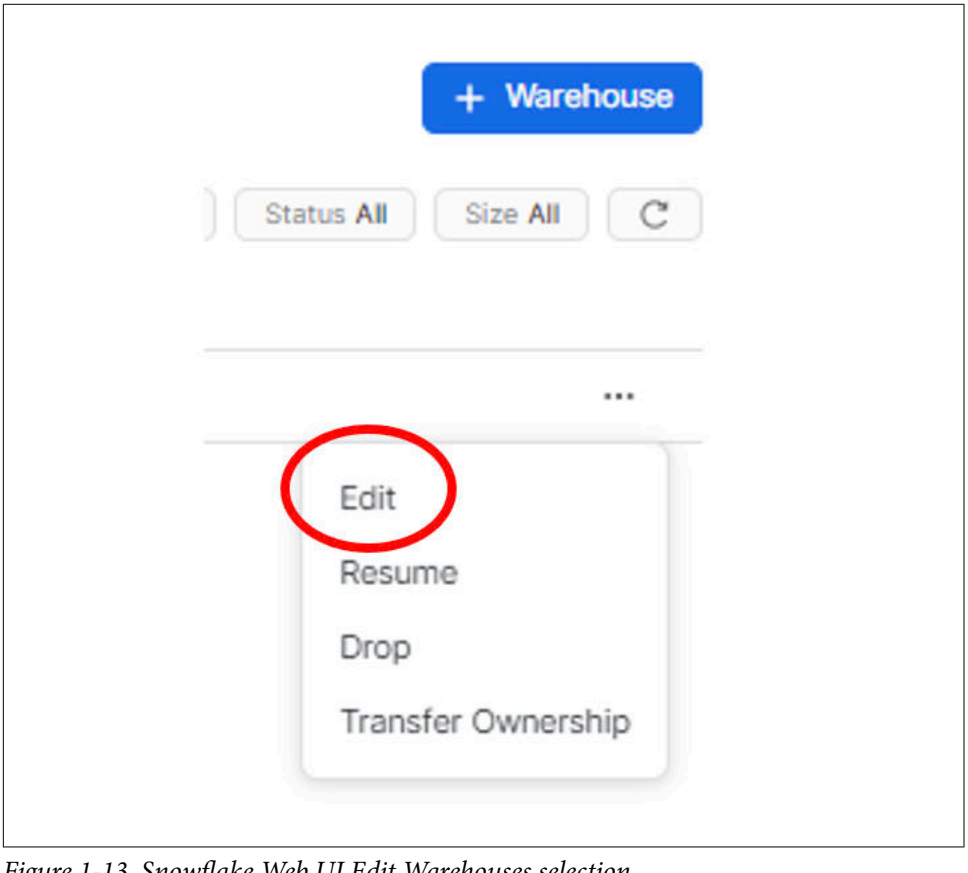



*Figure 1-13. Snowflake Web UI Edit Warehouses selection*

You should now see the Edit Warehouse screen as shown in Figure 1-14.

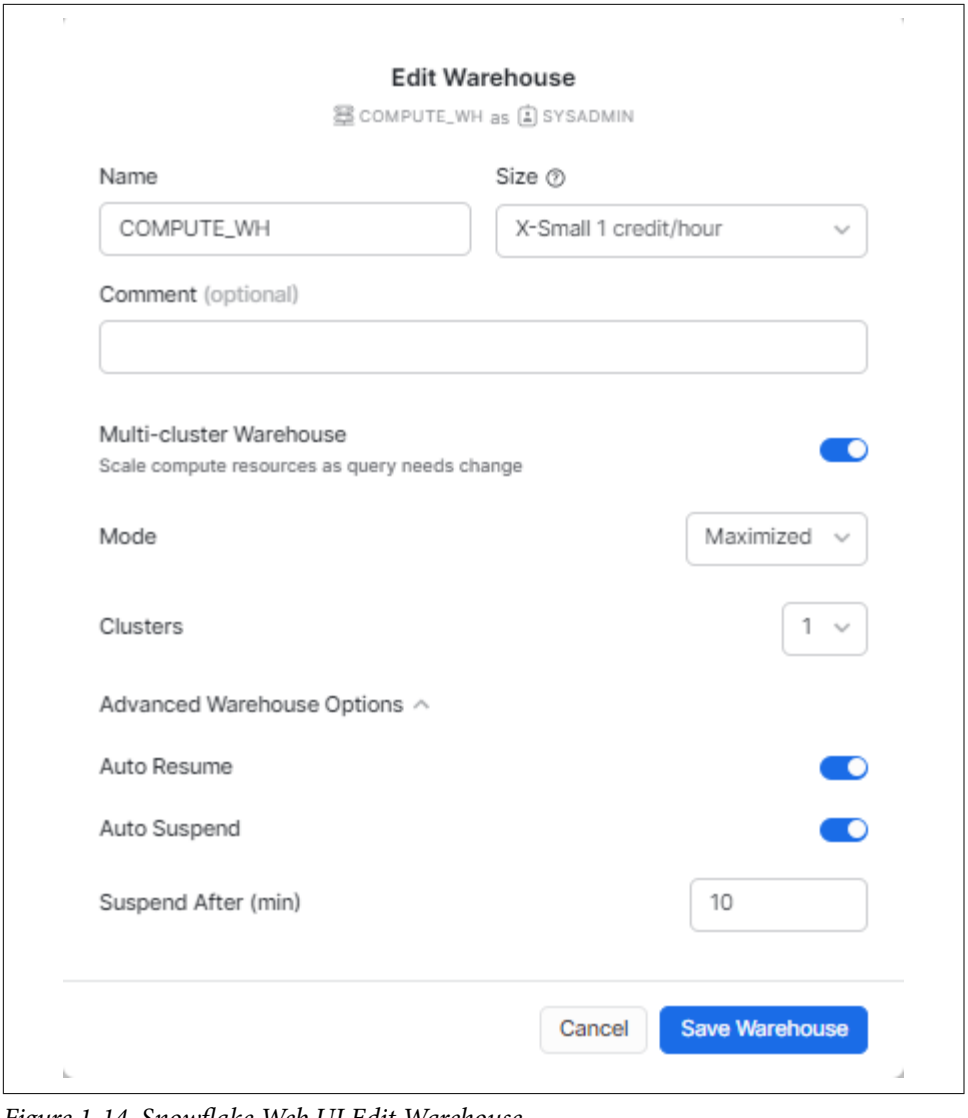



*Figure 1-14. Snowflake Web UI Edit Warehouse*

Rather than editing an existing virtual warehouse, you could choose to create a new virtual warehouse. While in the Warehouses sub-section of the Compute menu, you can add a new virtual warehouse by clicking on the button as shown in Figure 1-15.


*Figure 1-15. Snowflake Web UI to add a new virtual warehouse*

A multi-cluster virtual warehouse can be easily created in the Web UI as well as with SQL code in the Worksheet. Note that for Enterprise Edition, Business Critical Edition, and Virtual Private Snowflake Editions, multi-cluster warehouses are enabled. You are able to add a multi-cluster warehouse by toggling on that option, as shown in Figure 1-16.

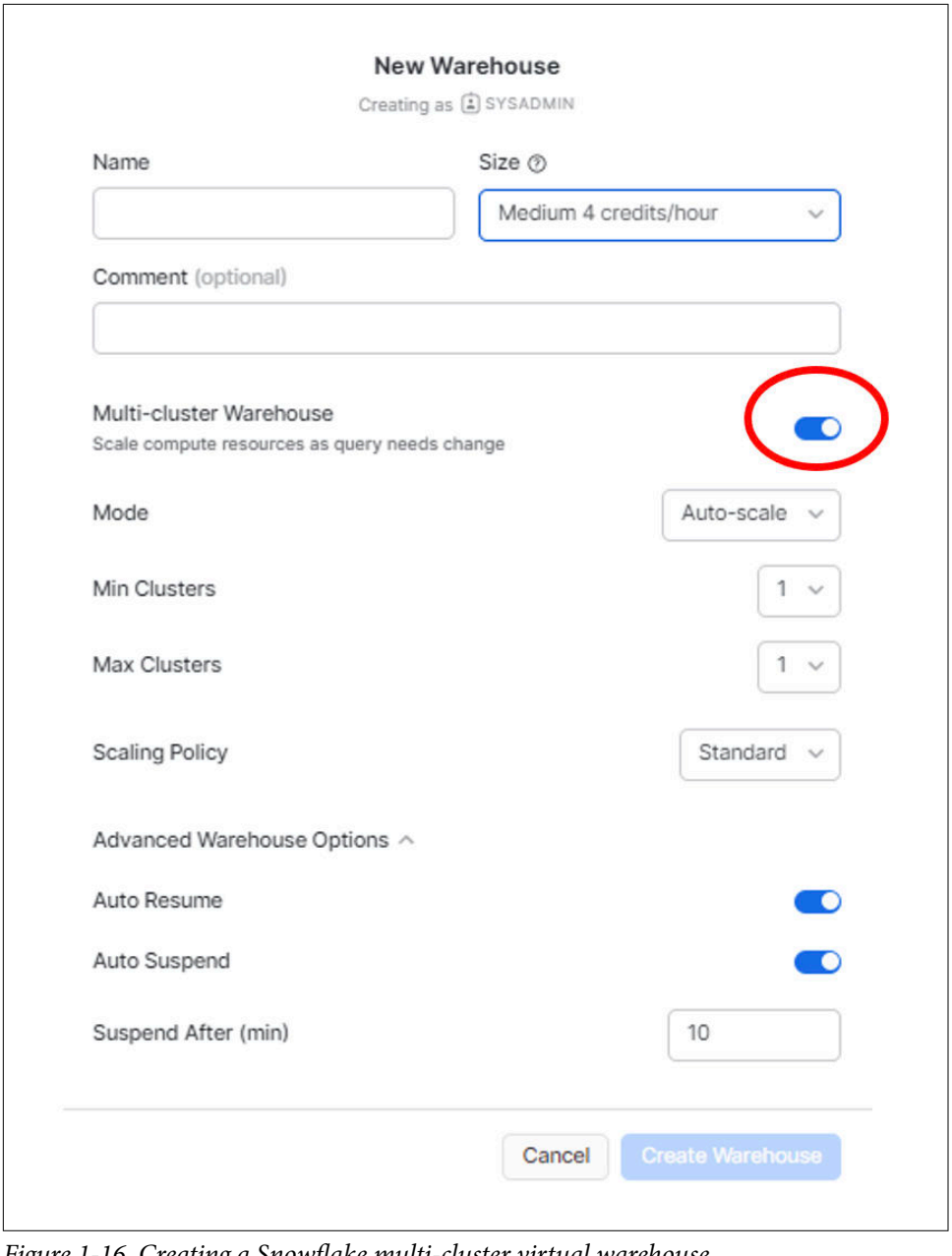



*Figure 1-16. Creating a Snowflake multi-cluster virtual warehouse*

To create a Snowflake multi-cluster virtual warehouse, you'll need to specify the scaling policy as well as the minimum and maximum number of clusters. As stated previ-

ously, the scaling policy, which applies only if the warehouse is running in Auto-scale mode, can be either economy or standard.

A multi-cluster virtual warehouse is said to be maximized when the minimum number of clusters and maximum number of clusters are the same. Additionally, value(s) must be more than one. An example of a maximized multi-cluster virtual warehouse is MIN_CLUSTER_COUNT = 3 MAX_CLUSTER_COUNT = 3.

## Separation of Workloads and Workload Management

Query processing tends to slow down when the workload reaches full capacity on traditional database systems. In contrast, Snowflake estimates resources needed for each query and as the workload approaches 100%, each new query is suspended in a queue until there are sufficient resources to execute them. Handling the queues can be accomplished in multiple ways. One way is to separate the workloads by assigning different warehouses to different users or groups of users (Figure 1-17). Another way is to take advantage of multi-cluster warehouses and their ability to automatically scale in and out (Figure 1-11). These two approaches are not mutually exclusive.

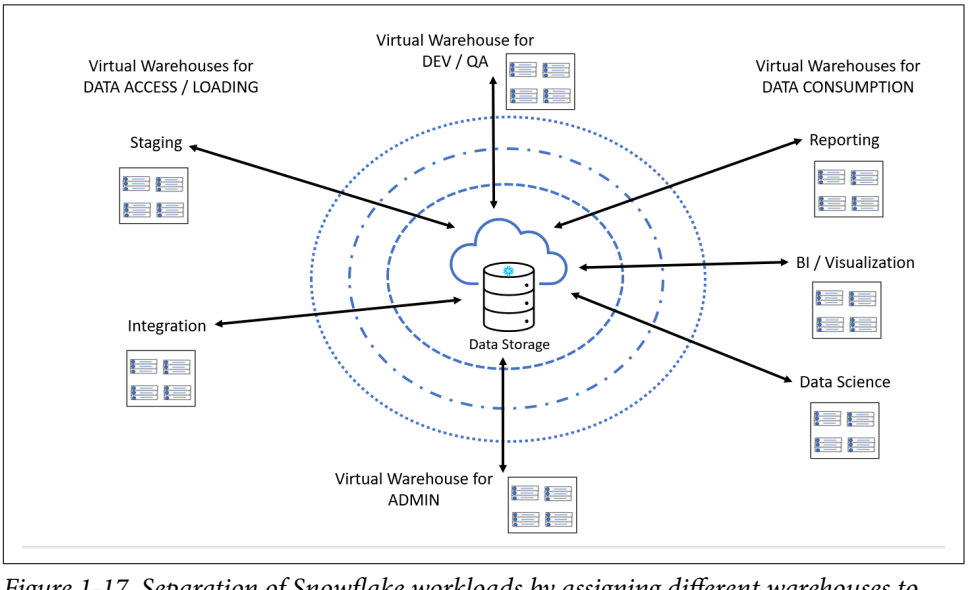



*Figure 1-17. Separation of Snowflake workloads by assigning different warehouses to groups of users*

Different groups of users can be assigned to different Snowflake virtual warehouses of varying sizes. Thus, users who are querying the data will experience an average query time that is consistent. Marketing and Sales can create and evaluate campaigns while

also capturing sales activities. Accounting and Finance departments can access their reports and delve into the details of the underlying data. Data scientists can run large complex queries on vast amounts of data. And ETL processes can continuously load data.

We learned earlier in the chapter that multi-cluster warehouses can be set to automatically scale to avoid concurrency problems. For an automatically scaling multi-cluster warehouse, we will still need to define the warehouse size and the minimum and maximum number of clusters. Previously, we saw how to create a new warehouse through the Snowflake UI. Now let's use SQL to create a multi-cluster virtual warehouse for our Accounting and Finance, then take a look at an example of how auto-scaling for that warehouse might work.

```
CREATE WAREHOUSE ACCOUNTING WITH Warehouse_Size = MEDIUM MIN_CLUSTER_COUNT = 1
MAX_CLUSTER_COUNT = 6 SCALING_POLICY = 'STANDARD';
```

The scaling process occurs automatically once the multi-cluster warehouse is configured. Figure 1-18 illustrates how auto-scaling works when the number of concurrent SQL statements increase.

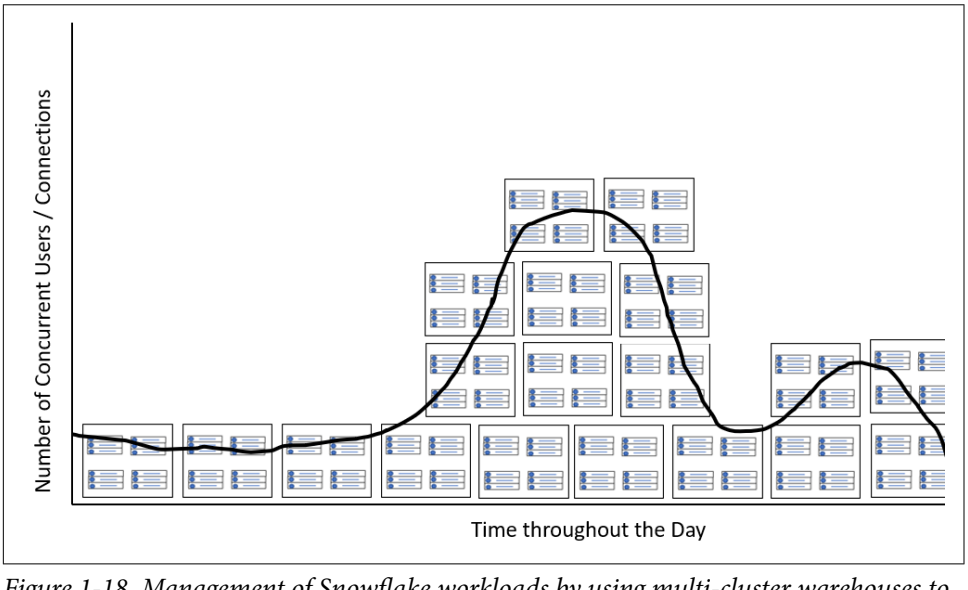



*Figure 1-18. Management of Snowflake workloads by using multi-cluster warehouses to scale in and out*

You can see that on an hourly basis, the workload is heavier between core working hours for employees. We might also want to investigate to confirm that the daily the workload is heavier overall at the beginning of the month for the Consumption virtual warehouse for Reporting, as the accounting department works to prepare and review the accounting statements for the prior month.

## Billing for Virtual Warehouse Layer

Consumption charges for Snowflake virtual warehouses are calculated based on the warehouse size, as determined by the number of servers per cluster, the number of clusters if there are multi-cluster warehouses, and the amount of time each cluster server runs. Snowflake utilizes per-second billing with a 60-second minimum each time a warehouse starts or is resized. When a warehouse is scaled up, credits are billed for one minute of the additional resources that are provisioned. All billing, even though calculated in seconds, is reported in fractions of hours.

When using the ACCOUNTADMIN role, you can view the warehouse credit usage for your account by clicking on Account > Usage in the UI. You can also query the Account Usage view in the SNOWFLAKE shared database to obtain the information. It is recommended that you choose an XS (extra small) warehouse to do so because of the small size of the data set and simplicity of the query.

# Centralized (Hybrid-Columnar) Database Storage Layer

Snowflake's centralized database storage layer holds all data, including structured and semi-structured data. As data is loaded into Snowflake, it is optimally reorganized into a compressed, columnar format and stored and maintained in Snowflake databases. Each Snowflake database consists of one or more schemas, which is a logical grouping of database objects such as tables and views. Chapter 3 is entirely devoted to showing you how to create and manage databases and database objects. In Chapter 9, we will learn about Snowflake's physical data storage as we take a deep dive into micro partitions to better understand data clustering.

Data stored in Snowflake databases is always compressed and encrypted. Snowflake takes care of managing every aspect of how the data is stored. Snowflake automatically organizes stored data into micro-partitions, an optimized immutable compressed columnar format, which is encrypted using AES-256 encryption. Snowflake optimizes and compresses data to make metadata extraction and query processing easier and more efficient. We learned earlier in the chapter that whenever a user submits a Snowflake query, that query will be sent to the cloud services optimizer before being sent to the compute layer for processing

Snowflake's data storage layer is sometimes referred to as the Remote Disk layer. The underlying file system is implemented on Amazon, Microsoft, or Google Cloud (Figure 1-19). The specific provider used for data storage is the one you selected when you created your Snowflake account. Snowflake doesn't place limits on the amount of data you can store or on the number of databases or database objects that you can create. Snowflake tables can easily store petabytes of data. There is no effect on virtual warehouse sizes as the storage increases or decreases in a Snowflake

account. The two are scaled independently from each other and from the cloud services layer.

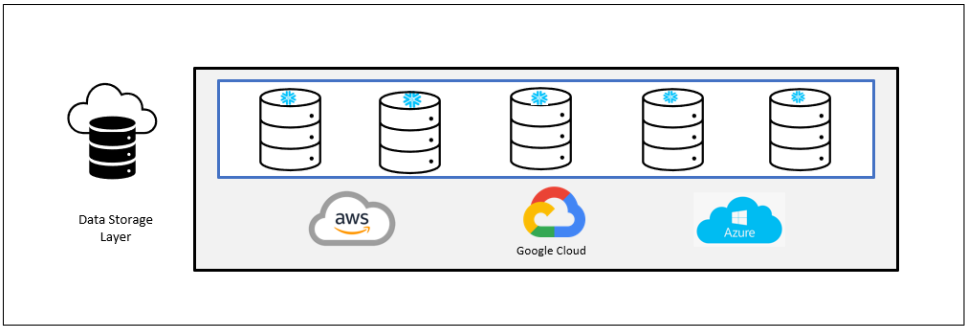



*Figure 1-19. Snowflake Data Storage Layer*

There are two unique features in the storage layer architecture – time travel and zero-copy cloning. Both very powerful Snowflake features will be introduced in this chapter and will be covered in more detail in later chapters. To prepare for those later chapters, you'll want to have a thorough understanding of these two features.

## Introduction to Zero Copy Cloning

Zero-copy cloning offers the user a way to "snapshot" a Snowflake database, schema, or table along with its associated data. There is no additional storage charge until changes are made to the cloned object because zero-copy data cloning is a metadata-only operation. For example, if you clone a database and then add a new table or delete some rows from a cloned table, at that point then there would be storage charges assessed. There are many uses for zero-copy cloning other than creating a backup. Most often, zero-copy clones will be used to support development and test environments. We'll see examples of this in Chapter 8.

## Introduction to Time Travel

Time travel allows you to restore a previous version of a database, table, or schema. This is an incredibly helpful feature that gives you an opportunity to fix previous edits incorrectly done or to restore items deleted in error. With time travel, you can also back up data from different points in the past by combining the time travel feature with the clone feature, or you can perform a simple query of a database object that no longer exists. How far back you can go into the past depends on a few different factors. Time travel will be discussed in detail in Chapter 7. For the purposes of this chapter, it is important to note that there will be data storage fees assessed for any data that has been deleted but is still available to restore.

## Billing for Storage Layer

Snowflake data storage costs are calculated based on the daily average size of compressed rather than uncompressed, data. Storage costs include the cost of persistent data stored in permanent tables and files staged for bulk data loading and unloading. Fail-safe data and the data retained for data recovery using time travel are also considered in the calculation of data storage costs. Clones of tables referencing data that has been deleted are similarly considered.

# Snowflake Caching

When you submit a query, Snowflake checks to see if that query has been previously run and, if so, whether the results are still cached. Snowflake will use the cached result set if it is still available rather than executing the query you just submitted. In addition to retrieving the previous query results from a cache, Snowflake supports other caching techniques. There are three Snowflake caching types; query results cache, virtual warehouse cache, and metadata cache.

## Query Results Cache

The fastest way to retrieve data from Snowflake is by using the query results cache. The results of a Snowflake query are cached, or persisted, for 24 hours and then purged. This contrasts with how the warehouse cache and metadata cache work. Neither of those two caches are purged based on a timeline. Even though the results cache only persists for 24 hours, the clock is reset each time the query is re-executed up to a maximum of 31 days from the date and time when the query was first executed. After 31 days, or sooner if the underlying data changes, a new result is generated and cached when the query is submitted again.

The results cache is fully managed by the Snowflake global cloud services (GCS) layer, as shown in Figure 1-20, and is available across all virtual warehouses since virtual warehouses have access to all data. The process for retrieving cached results is managed by GCS. However, once the size of the results exceeds a certain threshold, the results are stored in and retrieved from cloud storage.

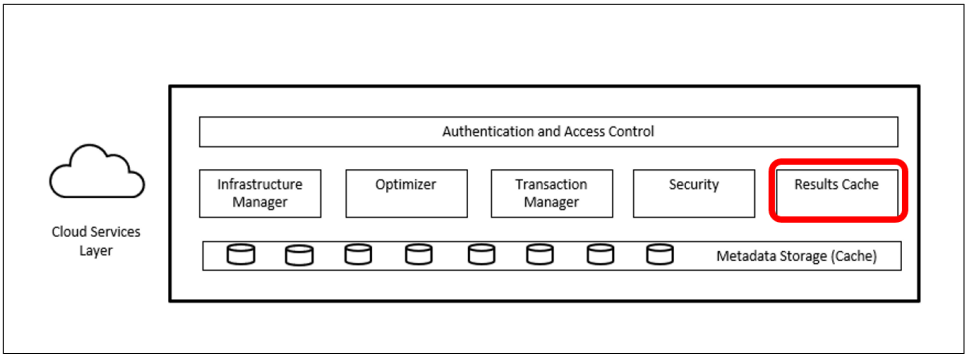



*Figure 1-20. Results Cache in the Snowflake Cloud Services Layer*

Query results returned to one user are also available to any user who has the necessary access privileges and who executes the same query. Therefore, any user can run a query against the result cache with no running virtual warehouse needed, assuming the query is cached and the underlying data has not changed.

Another unique feature of the query results cache is that it is the only cache that can be disabled by a parameter.

```
ALTER SESSION SET USE_CACHED_RESULT=FALSE;
```

Disabling the result cache is necessary to do before performing A/B testing and it is important to enable query result caching once the testing is complete.

## Metadata Cache

The metadata cache is fully managed in the global services layer (Figure 1-21) where the user does have some control over the metadata but no control over the cache.

Snowflake collects and manages metadata about tables, micro-partitions, and even clustering. For tables, Snowflake stores row count, table size in bytes, file references and table versions. Thus, a running warehouse will not be needed because the count statistics are kept in the metadata cache when running a SELECT COUNT(*) on a table.

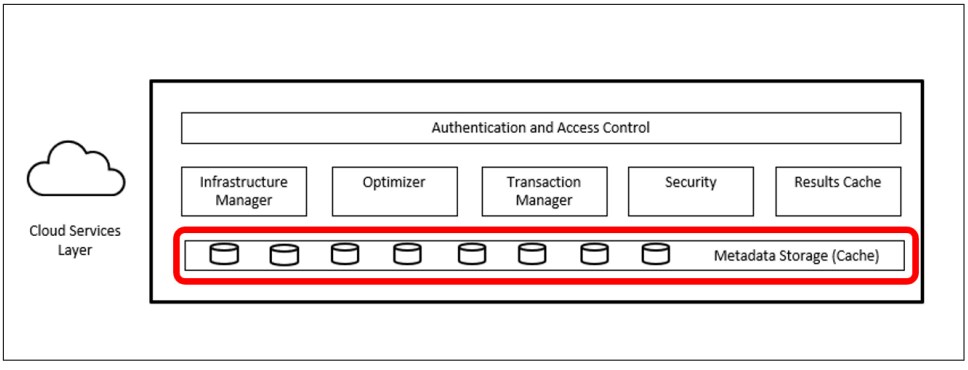



*Figure 1-21. Metadata Storage Cache in the Snowflake Cloud Services Layer*

The Snowflake metadata repository includes table definitions and references to the micro-partition files for that table. The range of values in terms of MIN and MAX, the NULL count, and the number of distinct values are captured from micro-partitions and stored in Snowflake. As a result, any queries which return the MIN or MAX value, for example, will not need a running warehouse. Snowflake stores the total number of micro-partitions and the depth of overlapping micro-partitions to provide information about clustering.

The information stored in the metadata cache is used to build the query execution plan.

## Virtual Warehouse Local Disk Cache

The traditional Snowflake data cache is specific to the virtual warehouse used to process the query. Running virtual warehouses use SSD storage to store the micro-partitions that are pulled from the centralized database storage layer when a query is processed. This is necessary to complete the query requested, whenever a query is executed. The size of the warehouse's SSD cache is determined by the size of the virtual warehouse's compute resources (Figure 1-22). Whenever a virtual warehouse receives a query to execute, that warehouse will scan the SSD cache first before accessing the Snowflake remote disk storage. Reading from SSD is faster than from the database storage layer but still requires the use of a running virtual warehouse.

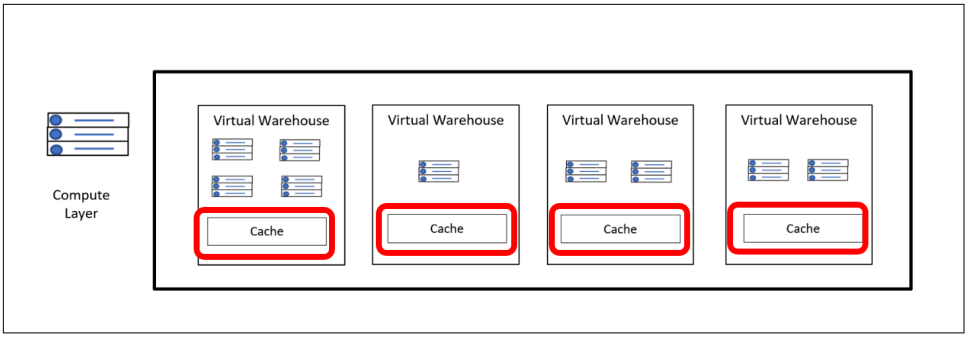



*Figure 1-22. Virtual Warehouse Cache in the Snowflake Cloud Services Layer*

Although the warehouse cache is implemented in the virtual warehouse layer where each virtual warehouse operates independently, the global services layer handles the overall system data freshness. It does so via the query optimizer which checks the freshness of each data segment of the assigned warehouse and then builds a query plan to update any segment by replacing it with data from the remote disk storage.

Note that the virtual warehouse cache is sometimes referred to as the "raw data cache", the "SSD cache", or the "data cache." This cache is dropped once the virtual warehouse is suspended, so you'll want to consider the trade-off between the credits that will be consumed by keeping a warehouse running versus the value from maintaining the cache of data from previous queries to improve performance. By default, Snowflake will automatically suspend a virtual warehouse after 10 minutes of idle time, but this can be changed.

Whenever possible, and where it makes sense, assign the same virtual warehouse to users who will be accessing the same data for their queries. This increases the likelihood that they will benefit from the virtual warehouse local disk cache.

## Get Ready for Hands-On Learning!

Hopefully these first two chapters have given you an understanding of the power of the Snowflake Data Cloud and its simplicity of use. In the upcoming chapters, we'll be demonstrating how Snowflake works by deep diving into hands-on learning examples throughout each of the chapters. If you haven't already done so, now is a good time to sign up for a Snowflake free trial account. Refer to Chapter 1 for more details on getting set up in a trial account.

## Exercises to Test Your Knowledge

The following exercises are based on the coverage in this chapter.

1. Name the three Snowflake architecture layers.
2. Which of the three Snowflake layers are multi-tenant?
3. In which of the three Snowflake architecture layers will you find the warehouse cache? the result cache?
4. If you are experiencing higher than expected costs for Snowflake cloud services, what kinds of things might you want to investigate?
5. Explain the difference between scaling up and scaling out.
6. What effect does scaling up or scaling out have on storage used in Snowflake?
7. Shared-nothing architecture evolved from shared-disk architecture. NoSQL alternatives have also been created. What one main problem have they all been trying to solve?
8. In a Snowflake multi-cluster environment, what scaling policies can be selected?
9. What components do you need to configure specifically for multi-cluster warehouses?
10. What are two options to change the warehouse that will be used to run a SQL command within a specific worksheet?

Solutions to these exercises are available in Appendix A.

CHAPTER 2

# Creating and Managing Snowflake Architecture Objects

## A Note for Early Release Readers

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

This will be the 3rd chapter of the final book.

If you have comments about how we might improve the content and/or examples in this book, or if you notice missing material within this chapter, please reach out to the editor at *mcronin@oreilly.com*.

Within Snowflake, all data is stored in database tables logically structured in collections of rows and columns. This chapter focuses on the logical structure of databases and database objects, such as tables and views.

In this chapter, we will cover topics in specific order because the series of examples in each topic build upon each other. The code is provided for you here in the chapter as well as on Github. These are the topics we will work through together:

1. Databases
2. Schemas
3. Information Schema and Account Usage
4. Tables
5. Views

6. Stages, File Format Included
7. Stored Procedures, Task Included
8. UDFs
9. Pipes, streams, and sequences
10. Code Cleanup and Test Your Knowledge

Our initial discussion here of databases, tables, views, stages, pipes, and streams lay the foundation for following chapters where we do a deeper dive into these objects. We will also conduct a deep dive for the User Defined Function (UDF) and Stored Procedure objects. One advanced deep dive example includes using a file format object and another example uses a task object. Pipes, streams, and sequences are briefly introduced and covered in more detail in later chapters.

## Creating and Managing Snowflake Databases

In the relational world, database objects such as tables, views, and more, are maintained within databases. In Snowflake, the database logically groups the data while the schema organizes it. Together, the database and schema comprise the *namespace*. In the examples throughout this chapter, whenever we work with database objects, we'll need to specify a namespace unless the schema and database we want to use are the active context in the workspace. If the database or schema needs to be specified, we'll include the "USE" command. That way, it is clear to Snowflake the location where objects are to be created or which specific object is being referenced in the commands.

There are two main types of databases we can create – permanent (persistent) and transient databases. At the time we create a database, the default will be a permanent database, if we don't specify which of the two types we want to create.

Snowflake is designed so that your data is accessible and recoverable at every stage within the data lifecycle. This is achieved through Continuous Data Protection (CDP), Snowflake's comprehensive set of features that help protect data stored in Snowflake against human error, malicious acts, and software or hardware failure. The important Snowflake CDP features introduced in this chapter are time travel and fail-safe.

Transient databases have a maximum one-day data retention period, aka *time-travel* period, and do not have a *fail-safe* period.

The Snowflake time travel period is the time during which table data within the database can be queried at a point in time. This also enables databases and database objects to be cloned or "undropped" and historical data to be restored. The default

time travel period is one day but can be up to 90 days for permanent databases; or a user could set the time travel period to zero days if no time travel period is desired. Note that Enterprise Edition or up is necessary to take advantage of the 90-day time travel period.

Snowflake's fail-safe data recovery service provides a seven-day period during which data from permanent databases and database objects may be recoverable by Snowflake. The fail-safe data recovery period is the seven-day period *after* the data retention period ends. Unlike time-travel data, which is accessible by Snowflake users, fail-safe data is recoverable *only* by Snowflake employees.

It is important to note that data storage costs are incurred for those seven days. That is one consideration when deciding about the database type you want to create. Another consideration is the ability to recover data from other sources if the data stored in the database is lost after a single data time travel period is up.

These are the basic SQL commands for Snowflake databases that we will be covering in this section:

- CREATE DATABASE
- ALTER DATABASE
- DROP DATABASE
- SHOW DATABASES

CREATE DATABASE is the command used to create a new database, clone an existing database, create a database from a share provided by another Snowflake account, or to create a replica of an existing primary database (i.e., a secondary database).

We can create databases from the User Interface (UI) or by using SQL code in the Snowflake worksheet. We created a database and database objects in Chapter 1 using the Web User Interface. We'll be using SQL commands in the Snowflake Worksheet for this chapter.

For all exercises in this chapter, make sure you have your role set to SYSADMIN throughout the chapter unless otherwise directed.

Let's go ahead and get started. We'll create one permanent database and one transient database.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE DATABASE CHAPTER3_PDB1 Comment = "Permanent Database 1 used for Exerci-
ses in Definitive Guide";
```

```
CREATE
OR REPLACE TRANSIENT DATABASE CHAPTER3_TDB1 Comment = "Transient Database 1 used
for Exercises in Definitive Guide";
```

Notice above that we used the words "OR REPLACE" optional keyword in the command. That way, an error would not be returned if the database already exists, though the existing database would be completely overwritten.

Use the CREATE OR REPLACE statement sparingly in production so as not to overwrite an existing database. As an alternative, if you don't want to have an error but also don't want to overwrite an existing database, use the CREATE DATABASE CHAPTER3_PDB1 IF NOT EXISTS; statement instead. The OR REPLACE and IF NOT EXISTS cannot both be used in the same statement.

Whenever you create a new database, that database is automatically set as the active database for the current session. It's the equivalent of using the "USE DATABASE" command. If we needed or wanted to use a database, other than the one we just created, we'd have to include the "USE DATABASE" command in the worksheet to select the appropriate database.

If you navigate to the Databases UI, as shown in Figure 2-1, you will see that it shows the two databases we just created plus three out of the four databases that automatically come with the Snowflake account.

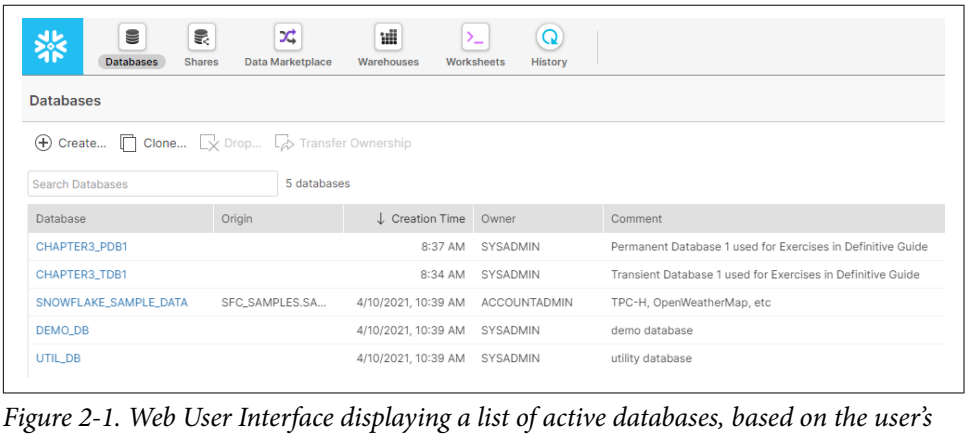



*Figure 2-1. Web User Interface displaying a list of active databases, based on the user's SYSADMIN role*

By default, the SNOWFLAKE database is shown only to those using the ACCOUNTADMIN role. However, that privilege can be granted to other roles.

Let's switch back to the Worksheets and change our role to ACCOUNTADMIN and see if we can view the SNOWFLAKE database. Once in the worksheet:

```
USE ROLE ACCOUNTADMIN;
SHOW DATABASES;
```

Notice in Figure 2-2 that all databases, including the ones we just created, have a 1-day retention time. Data retention time (in days) is the same as the time travel number of days and specifies the number of days for which the underlying data is retained after deletion, and for which "CLONE" and "UNDROP" commands can be performed on the database.

| Row | created_on | name | is_default | is_current | origin | owner | comment | options | retention_time |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2021-04-25 06:37:59.72... | CHAPTER3_PDB1 | N | Y | | SYSADMIN | Permanent Database 1 us... | | 1 |
| 2 | 2021-04-25 06:48:57.60... | CHAPTER3_TDB1 | N | N | | SYSADMIN | Transient Database 1 use... | TRANSIENT | 1 |
| 3 | 2021-04-10 08:39:08.54... | DEMO_DB | N | N | | SYSADMIN | demo database | | 1 |
| 4 | 2021-04-10 08:39:03.24... | SNOWFLAKE | N | N | SNOWFLAKE.ACCOUNT_... | | | | 1 |
| 5 | 2021-04-10 08:39:09.20... | SNOWFLAKE_SAMPLE_D... | N | N | SFC_SAMPLES.SAMPLE_... | ACCOUNTADMIN | TPC-H, OpenWeatherMa... | | 1 |
| 6 | 2021-04-10 08:39:05.33... | UTIL_DB | N | N | | SYSADMIN | utility database | | 1 |

*Figure 2-2. Worksheet displaying a list of active Databases, based on the user's ACCOUNTADMIN role*

We can change the data retention time for a permanent database but not for a transient one. We can change the retention time up to 90 days for permanent databases. We'll go ahead and change the retention time for our permanent database to 10 days by using the "ALTER DATABASE" command. Be sure to change your role back to SYSADMIN before issuing the commands.

```
USE ROLE SYSADMIN;
ALTER DATABASE CHAPTER3_PDB1
SET
    DATA_RETENTION_TIME_IN_DAYS = 10;
```

If you attempt to change the data retention time for a transient database, you'll receive an error telling you that the value "10" is an invalid value for the parameter. That is because a transient database can have a maximum 1-day data retention. You could change the retention time to 0 days but then you wouldn't be able to "CLONE" or "UNDROP" that database if you do that.

We'll be covering tables in more detail in a later section, but for now, it is important to mention a few things about tables as they relate to permanent versus transient databases.

Snowflake uses a hybrid approach when it comes to permanent databases but not transient databases. A permanent database type is not limited to the different types of objects that can be stored within them. For example, you can store transient tables within a permanent database but not permanent tables within a transient database. As a reminder, transient tables are designed to hold transitory data that doesn't need the same level of protection and recovery as permanent tables but does still need to be maintained beyond a session.

Below is an example of creating a table in our transient database.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE TABLE "CHAPTER3_TDB1"."PUBLIC"."SUMMARY" (
    CASH_AMT number,
    RECEIVABLES_AMT number,
    CUSTOMER_AMT number
);
```

Notice we didn't specify the type of table as either permanent or transient. By default, Snowflake creates a permanent table unless you indicate otherwise when you are creating the table. The exception would be when you are creating a table within a transient database. In that case, the table would also have to be transient. By default, all tables created in a transient schema are transient. We can see that is the case by using the "SHOW TABLES" command which gives us the following result, shown in Figure 2-3, for the table we just created.

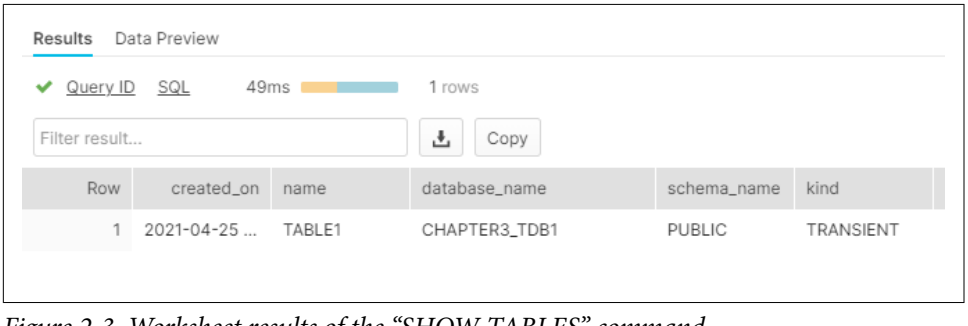



*Figure 2-3. Worksheet results of the "SHOW TABLES" command*

There is no limit to the number of database objects, schemas, and databases that can be created within a Snowflake account.

Each Snowflake account also comes with certain databases, schemas, and tables already included as shown in Figure 2-4 below. As shown, there are four databases that initially come with a Snowflake account:

- SNOWFLAKE database
- UTIL_DB database
- DEMO_DB database
- SNOWFLAKE_SAMPLE_DATA database

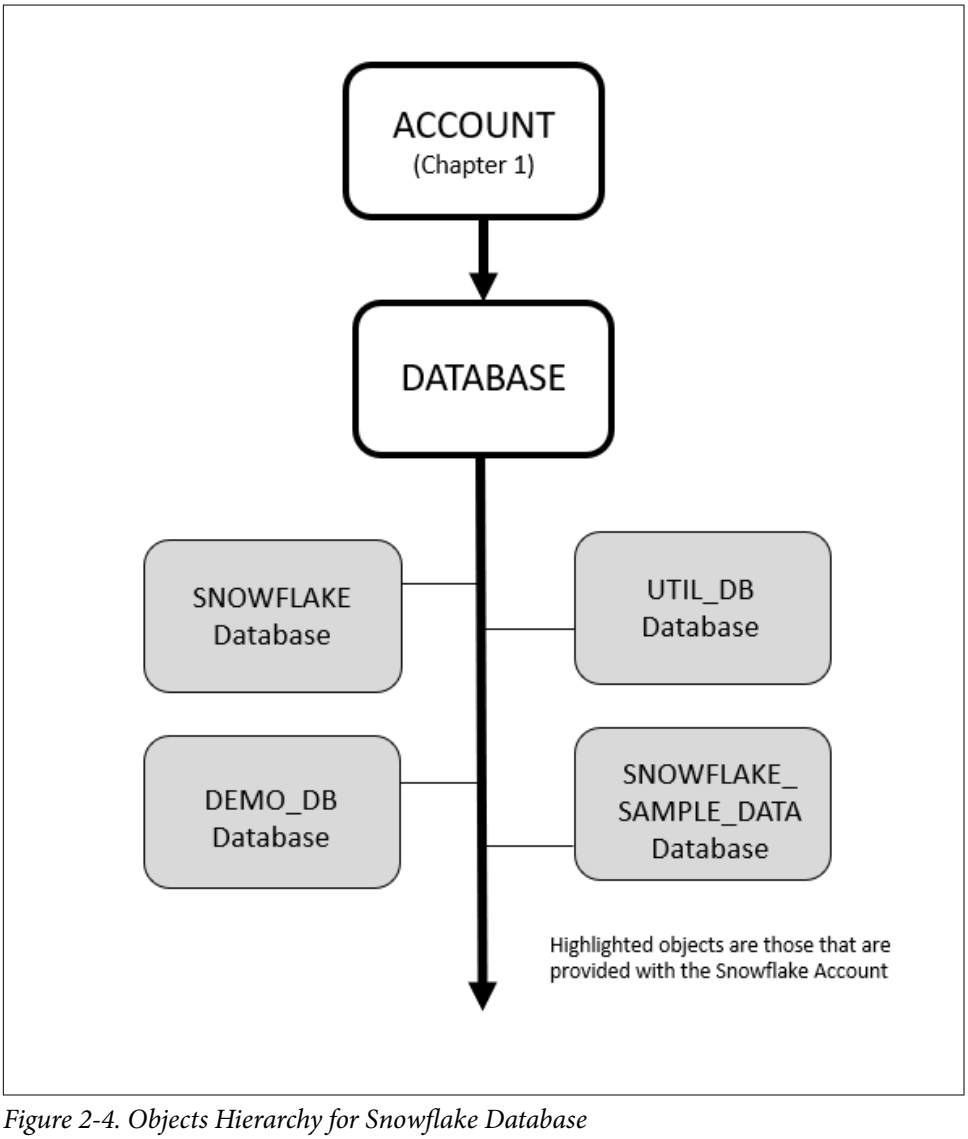



*Figure 2-4. Objects Hierarchy for Snowflake Database*

The SNOWFLAKE database is owned by Snowflake Inc. and is a system-defined, read-only shared database which provides object metadata and usage metrics about

your account. Unlike the other three databases imported into your account at the time of setup, the SNOWFLAKE database cannot be deleted from your account.

The UTIL_DB database and DEMO_DB database, also imported into your account at the time of setup, contains no data and, as such, there are no storage charges for those databases, and they can be dropped at any time.

Upon first look, the SNOWFLAKE_SAMPLE_DATA database appears to be something similar to what you might create in your Snowflake account. However, the sample database is actually one that has been shared from the Snowflake SFC_SAMPLES account and the database is read-only in your account which means that no DDL commands can be issued. In other words, database objects cannot be added, dropped, or altered within the sample database. In addition, no DML commands for actions such as cloning can be performed on the tables. You can, however, view the sample database and execute queries on the tables.

We'll be using the SNOWFLAKE_SAMPLE_DATA database in some of our examples in this chapter. In Chapter 10, we'll be learning about shared databases but, for now, what is important to know is that while we don't incur any storage costs for the shared sample database, we do need a running warehouse to run queries and so there will be an associated compute cost for running those queries on the Snowflake sample database.

Even though it may be obvious, one final important consideration for how to architect your solution and which objects to choose for storing data is that there is a monetary cost for storing data in Snowflake and there are also performance implications.

This chapter is intended to give you the necessary understanding of Snowflake databases and database objects as a foundation for later chapters which will address more complex topics such as improving performance and reducing costs, data recovery, and data loading and unloading.

## Creating and Managing Snowflake Schemas

When we created databases, we didn't have to specify the account because we can only operate in one account at a time. But when we create a schema, we need to let Snowflake know which database we want to use. If we don't specify a particular database, then Snowflake will use the one that is active.

Just like databases, schemas can be either permanent or transient with the default being permanent. Just like databases, we have available the same SQL commands. However, for schemas, we have something unique called a managed access schema. In a managed access schema, the schema owner manages grants on the objects within a schema, such as tables and views, but doesn't have any of the USAGE, SELECT, or DROP privileges on the objects.

There are different ways to create a schema that will achieve the same result. Here below are two examples that accomplish the same thing. In this first example, the "USE" command lets Snowflake know for which database the schema will be created.

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_PDB1;
CREATE
OR REPLACE SCHEMA BANKING;
```

In the second example, we simply use the *fully qualified schema name.*

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SCHEMA CHAPTER3_PDB1.BANKING;
```

If we use the "SHOW SCHEMA" command as demonstrated in Figure 2-5, we notice that the retention time of the new schema also has a retention time of 10 days, just like the database in which it was created, rather than the default 1-day retention.

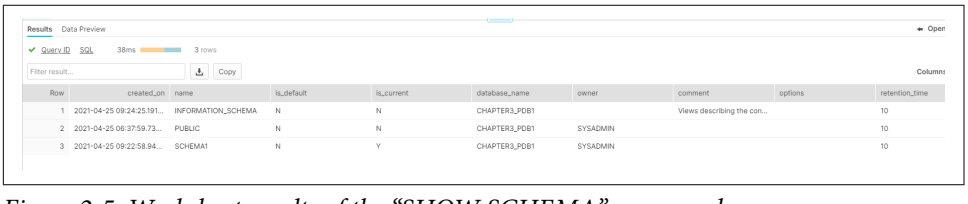



*Figure 2-5. Worksheet results of the "SHOW SCHEMA" command*

However, we can always change the retention time to one day for the schema.

```
USE ROLE SYSADMIN;
ALTER SCHEMA CHAPTER3_PDB1.BANKING
SET
    DATA_RETENTION_TIME_IN_DAYS = 1;
```

Now, run the "SHOW SCHEMAS" command again and you'll see the retention time has been changed for the schema.

If we'd like to create a schema with managed access, we need to add the "WITH MANAGED ACCESS" command.

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_PDB1;
CREATE
OR REPLACE SCHEMA MSCHEMA WITH MANAGED ACCESS;
```

Now, when you run the "SHOW SCHEMAS" command, you'll notice that "Managed Access" will be displayed under the options column for the schema named MSCHEMA.

As discussed in Chapter 5, for regular schemas the object owner role can grant object access to other roles and can also grant those roles the ability to manage grants for the object. However, in managed access schemas, object owners are unable to issue grant privileges. Instead, only the schema owner or a role with the MANAGE GRANTS privilege assigned to it can manage the grant privileges.

The SECURITYADMIN and ACCOUNTADMIN inherently have the "MANAGE GRANTS" privilege. Thus, both roles can manage the grant privileges on all managed schemas.

There are two database schemas, as shown in Figure 2-6, that are included in every database that is created: INFORMATION_SCHEMA and PUBLIC. The PUBLIC schema is the default schema and can be used to create any other objects whereas the INFORMATION_SCHEMA is a special schema for the system that contains views and table functions that provide access to the metadata for the database and account. The Information Schema will be discussed in the next section.

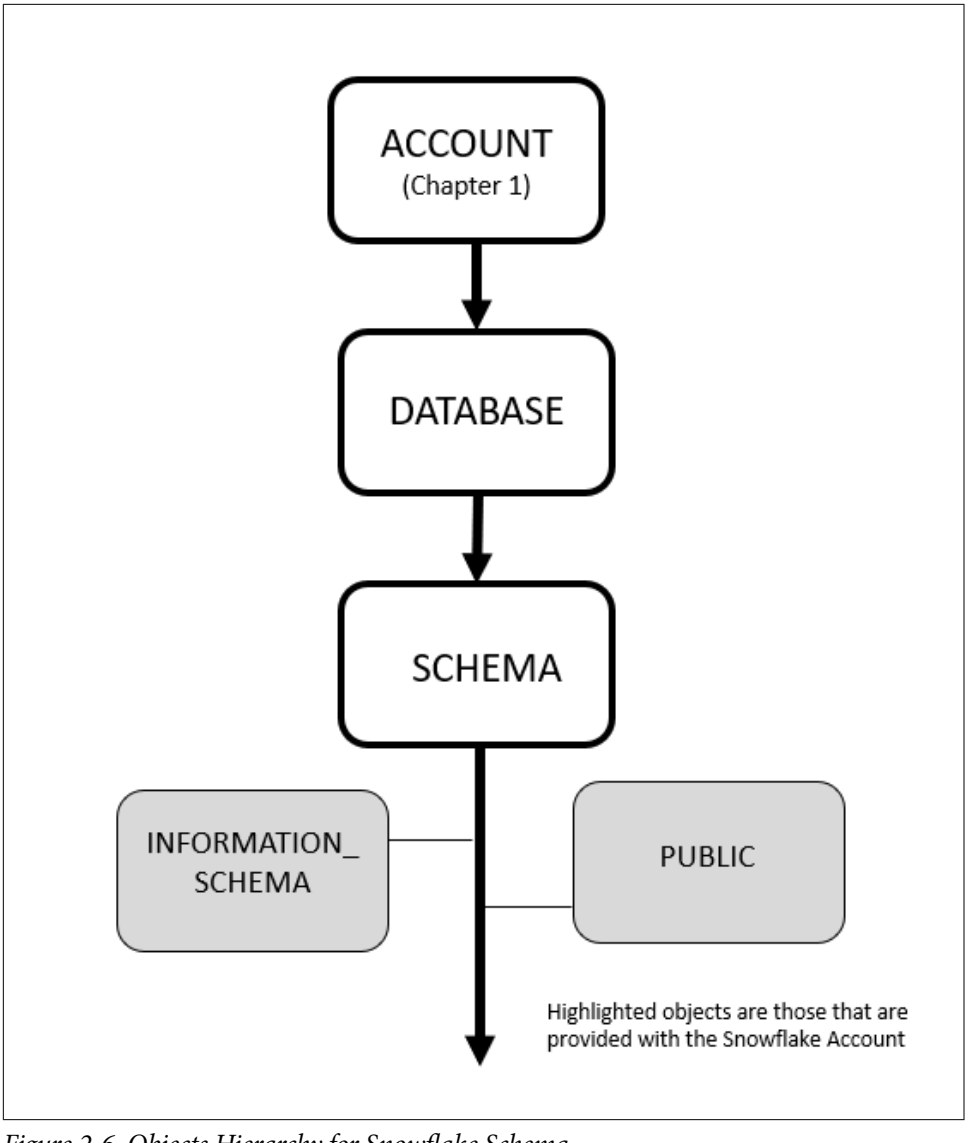



*Figure 2-6. Objects Hierarchy for Snowflake Schema*

## INFORMATION_SCHEMA and Account Usage

As we just learned, the Snowflake INFORMATION_SCHEMA is included within every database created in Snowflake. The Information Schema, also known as the "Data Dictionary", includes metadata information about the objects within the database as well as account-level objects like roles. In Chapter 8, we'll explore Information Schema table functions, which can be used to return historical information and

account usage information. For now, we'll be exploring Information Schema Database Views in a little more detail.

More than 20 system-defined views are included in every Information Schema and can be divided between account views and database views.

Information Schema Account Views:

- **Applicable_Roles**: Displays one row for each role grant
- **Databases:** Displays a row for each database defined in your account
- **Enabled_Roles**: Displays a row for each currently-enabled role in the session
- **Information_Schema_Catalog_Name**: the name of the database in which the information_schema resides
- **Load_History**: Displays one row for each file loaded into tables using the COPY INTO <table> command. Returns history for past 14 days except no history for data loaded using Snowpipe,
- **Replication_Databases**: Displays a row for each primary and secondary database (i.e., database for which replication has been enabled) in your organization

You may want to look at what is within each of these views. You'll notice that for some of them, all views in the account contain the same information. Try the SQL statements below. What do you notice?

```
SELECT
    *
FROM
    "SNOWFLAKE_SAMPLE_DATA"."INFORMATION_SCHEMA"."DATABASES";
SELECT
    *
FROM
    "DEMO_DB"."INFORMATION_SCHEMA"."DATABASES";



SELECT
    *
FROM
    "SNOWFLAKE_SAMPLE_DATA"."INFORMATION_SCHEMA"."APPLICABLE_ROLES";

SELECT
    *
FROM
    "DEMO_DB"."INFORMATION_SCHEMA"."APPLICABLE_ROLES";
```

Information Schema Database Views:

- **Columns**: Displays a row for each column in the tables defined in the specified (or current) database
- **External_Tables**: Displays a row for each external table in the specified (or current) database
- **File_Formats**: Displays a row for each file format defined in the specified (or current) database
- **Functions**: Displays a row for each user-defined function (UDF) or external function defined in the specified (or current) database
- **Object_Privileges**: Displays a row for each access privilege granted for all objects defined in your account.
- **Pipes:** Displays a row for each pipe defined in the specified (or current) database
- **Procedures:** Displays a row for each stored procedure defined the specified (or current) database
- **Referential_Constraints**: Displays a row for each referential integrity constraint defined in the specified (or current) database
- **Schemata:** Displays a row for each schema in the specified (or current) database,
- **Sequences**: Displays a row for each sequence defined in the specified (or current) database
- **Stages:** Displays a row for each stage defined in the specified (or current) database
- **Table_Constraints**: Displays a row for each referential integrity constraint defined for the tables in the specified (or current) database
- **Table_Privileges**: Displays a row for each table privilege that has been granted to each role in the specified (or current) database
- **Table_Storage_Metrics**: Displays table-level storage utilization information, includes table metadata, and displays the number of storage types billed for each table. NOTE: Rows are maintained in this view until the corresponding tables are no longer billed for any storage, regardless of various states that the data in the tables may be in (i.e. active, Time Travel, Fail-safe, or retained for clones)
- **Tables**: Displays a row for each table and view in the specified (or current) database
- **Usage_Privileges**: Displays a row for each privilege defined for sequences in the specified (or current) database
- **Views:** Displays a row for each view in the specified (or current) database

There are different ways to look at some of the metadata in Snowflake, some of which do use the Information Schema. If you try each of the commands below, you'll see

that there are two ways we can get the information about schemas within the Snowflake sample database.

```
SELECT
    *
FROM
    "SNOWFLAKE_SAMPLE_DATA"."INFORMATION_SCHEMA"."SCHEMATA";
SHOW SCHEMAS IN DATABASE "SNOWFLAKE_SAMPLE_DATA";
```

However, one thing you will notice is that the metadata contained with the INFORMATION_SCHEMA is much more complete with several more columns of information than when you simply use the "SHOW" command.

If you try the following SQL statement, what happens?

```
SELECT
    *
FROM
    "DEMO_DB"."INFORMATION_SCHEMA"."TABLE_PRIVILEGES";
```

You will notice that no rows are returned in the results. The reason is because there are no tables in the database, thus, there will be no table privileges.

The INFORMATION_SCHEMA, one of the two schemas that are included with every Snowflake database, has a great many uses. The Information Schema provides a great deal of information about an account's object metadata and usage metrics. There is also another place within Snowflake where object metadata and usage metrics are stored.

### Account Usage Schema

The SNOWFLAKE database, viewable by the ACCOUNTADMIN by default, includes an ACCOUNT_USAGE schema that is very similar to the INFORMATION_SCHEMA but with three differences. First, the SNOWFLAKE database ACCOUNT_USAGE schema includes records for dropped objects whereas the INFORMATION_SCHEMA does not. The ACCOUNT_USAGE schema also has a longer retention time for historical usage data. Whereas the INFORMATION_SCHEMA has data available ranging from seven days to six months, the ACCOUNT_USAGE view retains historical data for one year. Finally, there is no latency when querying the INFORMATION_SCHEMA but the latency time for ACCOUNT_USAGE could range from 45 minutes to three hours.

One of the common uses for the ACCOUNT_USAGE schema is to keep track of credits used over time by each warehouse in your account (month-to-date):

```
USE ROLE ACCOUNTADMIN;
USE DATABASE SNOWFLAKE;
USE SCHEMA ACCOUNT_USAGE;
SELECT
```

```
    start_time::date AS USAGE_DATE,
    WAREHOUSE_NAME,
    SUM(credits_used) AS TOTAL_CREDITS_CONSUMED
FROM
    warehouse_metering_history
WHERE
    start_time >= date_trunc(Month, current_date)
GROUP BY
    1,
    2
ORDER BY
    2,
    1;
```

The SNOWFLAKE database, which includes the Account Usage schema, is only available to the ACCOUNTADMIN role, unless the ACCOUNTADMIN grants imported privileges from the underlying share to another role. We'll explore the account_usage schema in more detail in future chapters, especially in Chapters 8 and 9 when we learn more about improving performance and reducing costs.

### Schema Object Hierarchy

In this section, we've learned about the schema object and explored the two schemas that come with each Snowflake database. A look back at Figure 2-6 shows us the schema object hierarchy that exists above the schema object. Next, we'll want to explore the Snowflake objects below the schema in the hierarchy.

Within a Snowflake schema object, there exists many objects including tables, views, stages, policies, stored procedures, user defined functions, and more. In the next sections, we'll take a closer look at several of these Snowflake objects. While we will explore some of these Snowflake objects in detail, the explanations in this chapter are meant to be foundational; we'll dive deeper into these objects throughout many of the subsequent chapters.

## Introduction to Snowflake Tables

As previously mentioned, all Snowflake data is stored in tables. In addition to permanent and transient tables, it is also possible to create temporary and external tables as shown in Figure 2-7. Like database and schemas, we can use the CREATE, ALTER, DROP, and SHOW TABLES commands. In addition, we'll need to use INSERT INTO or COPY INTO to place data in a table. For Snowflake tables, we can also use the TRUNCATE or DELETE command to remove data from a table but not remove the table object itself.

TRUNCATE and DELETE are different in that TRUNCATE also clear table load history metadata, while delete retains the metadata .

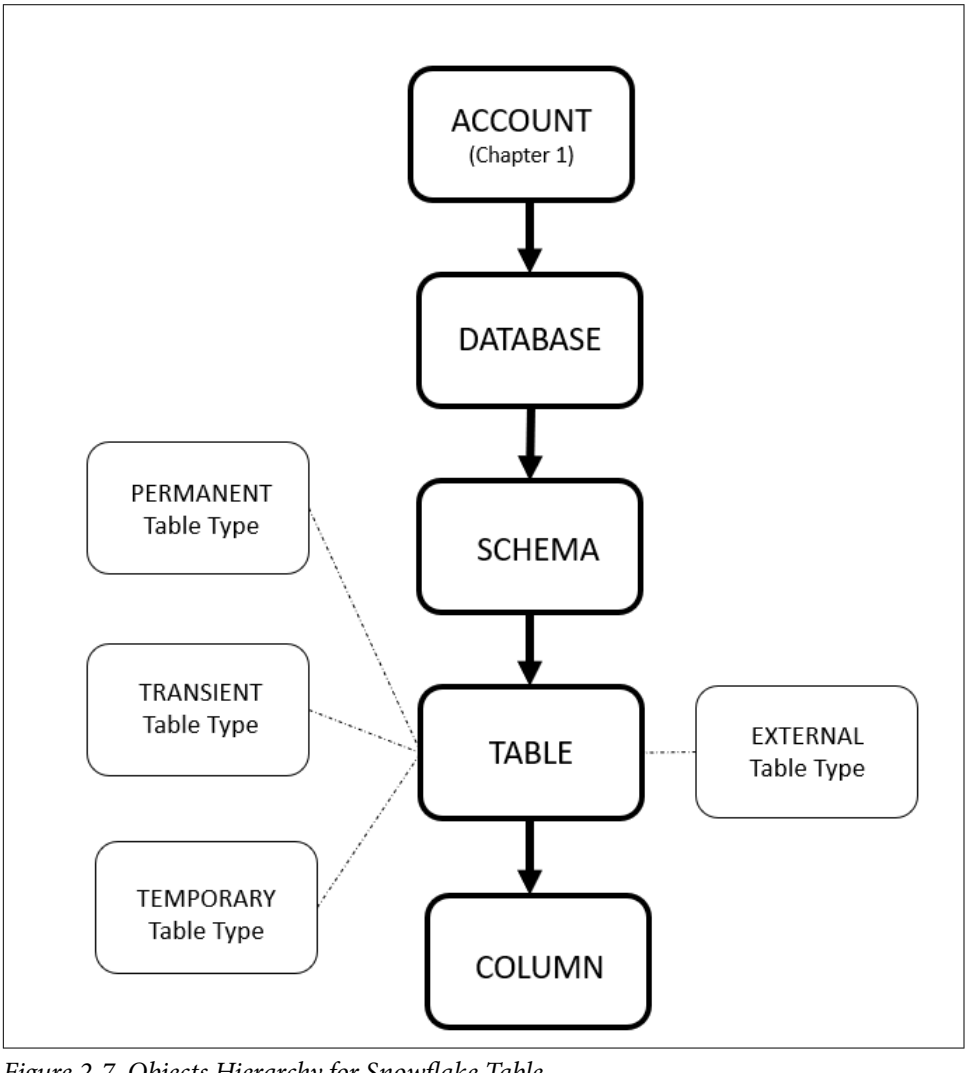



*Figure 2-7. Objects Hierarchy for Snowflake Table*

As we saw in the database section, Snowflake assumes it should create a permanent table if the table type is not specified, unless the table is created within a transient database.

Transient tables are unique to Snowflake and have characteristics of both permanent and temporary table. Transient tables are designed for transitory data that needs to be maintained beyond a session but doesn't need the same level of data recovery by permanent tables. As a result, the data storage costs for a transient table would be less than a permanent table. One of the biggest differences between transient tables and permanent tables is that the fail-safe service is not provided for transient tables.

It isn't possible to change a permanent table to a transient table by using the ALTER command because the TRANSIENT property is set at table creation time. Likewise, a transient table cannot be converted to a permanent table. If you would like to make a change to a transient or permanent table type, you'll need to create a new table, use the "COPY GRANTS" clause, and then copy the data. Using the COPY GRANTS clause will ensure that the table will inherit any explicit access privileges.

It was mentioned that the default for creating tables is that a permanent table would be created unless otherwise specified. If it makes sense to have new tables automatically created as a transient type by default, you can first create a transient database or schema. As we saw in the databases section, all tables created afterward will be transient rather than permanent.

Transient tables can be accessed by other users who have the necessary permissions. On the other hand, temporary tables exist only within the session in which they are created. This means they are not available to other users and cannot be cloned. Temporary tables have many uses including being used for ETL data and for session-specific data needs.

The temporary table, as well as its data within, is no longer accessible once the session ends. During the time a temporary table exists, it does count toward storage costs; therefore, it is a good practice to drop a temporary table once you no longer need it.

Interestingly, you can create a temporary table that has the same name as an existing table in the same schema since the temporary table is session-based. No errors or warnings will be given. It is also a best practice to give temporary tables unique names to avoid unexpected problems given that the temporary table takes precedence.

Table 3-1 summarizes some characteristics of the different Snowflake tables.

*Table 2-1. Snowflake Table Characteristics*

| Snowflake Tables | Permanent | Transient | Temporary | External |
|---|---|---|---|---|
| Persistence | Until explicitly dropped | Until explicitly dropped | Remainder of session | Until explicitly dropped |

| | | | | |
|---|---|---|---|---|
| Time Travel Retention (Days) | 0 – 90 days* | 0 or 1 | 0 or 1 | 0 |
| Fail-Safe Period (Days) | 7 | 0 | 0 | 0 |
| Cloning Possible | Yes | Yes | Yes | No |
| Create Views Possible | Yes | Yes | Yes | Yes |

*Enterprise Edition and above 0-90 days. Standard Edition 0 or 1 day.

We will now create some tables that we'll use later in the chapter:

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_PDB1;
CREATE
OR REPLACE SCHEMA BANKING;
CREATE
OR REPLACE TABLE CUSTOMER_ACCT (
    Customer_Account int,
    Amount int,
    transaction_ts timestamp
);
CREATE
OR REPLACE TABLE CASH (
    Customer_Account int,
    Amount int,
    transaction_ts timestamp
);
CREATE
OR REPLACE TABLE RECEIVABLES (
    Customer_Account int,
    Amount int,
    transaction_ts timestamp
);
```

After creating this table, the active role is the "SYSADMIN" role, the active database is "CHAPTER3_PDB1" and the active schema is "BANKING". Thus, a newly created table will be located within the BANKING schema if you create a new table without specifically using a different namespace. Let's try that now:

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE TABLE NEWTABLE (
    Customer_Account int,
    Amount int,
    transaction_ts timestamp
);
```

In Figure 2-8, we can see that NEWTABLE was created in the active namespace.

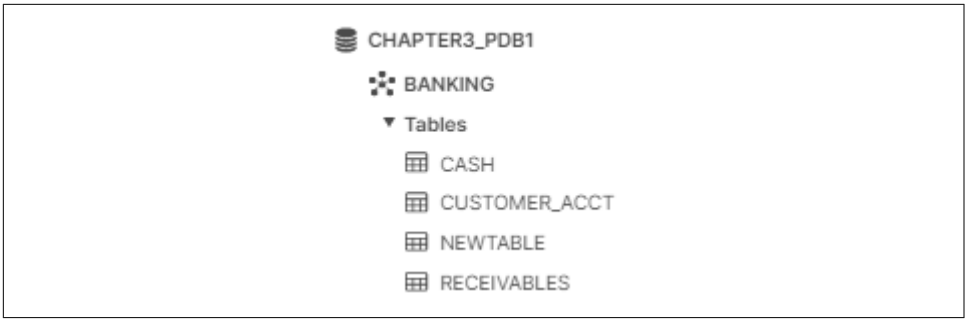



*Figure 2-8. List of the tables in the Banking schema of the CHAPTER3_PDB1 database*

Let's now drop the new table we just created. We want to use the fully qualified table name. Type in "DROP TABLE" with a space afterward. Then, double click on the table name and Snowflake will insert the fully qualified table name. Be sure to put a semi-colon at the end and then run the statement.

```
USE ROLE SYSADMIN;
DROP TABLE "CHAPTER3_PDB1"."BANKING"."NEWTABLE";
```

We weren't required to use the fully qualified table name because we were in the active space where we wanted to drop the table. We could have just used the command "DROP TABLE NEWTABLE;". However, it is best practice to use a table's fully qualified name or the "USE" command, which achieves the same goal.

At this point, Figure 2-9 shows what your Account should look like.

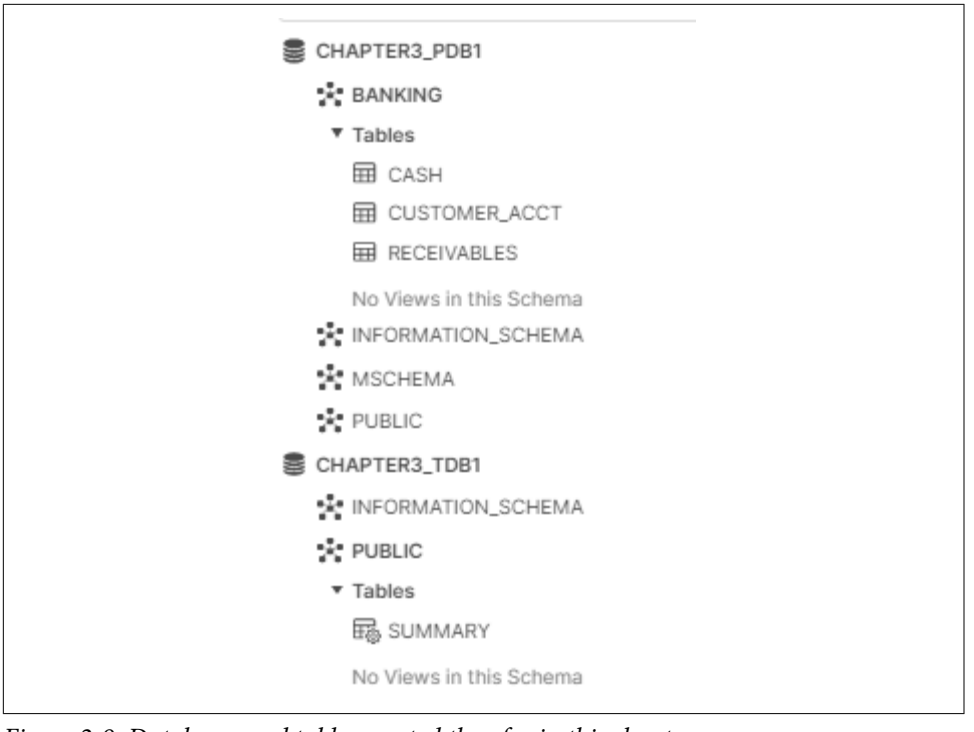



*Figure 2-9. Databases and tables created thus far in this chapter*

## Creating and Managing Views

Along with tables, Snowflake views are the primary objects maintained in database schemas as shown in Figure 2-10. Views are of two types, materialized and non-materialized. Whenever the term "view" is mentioned and the type is not specified, it is understood that it is a non-materialized view.

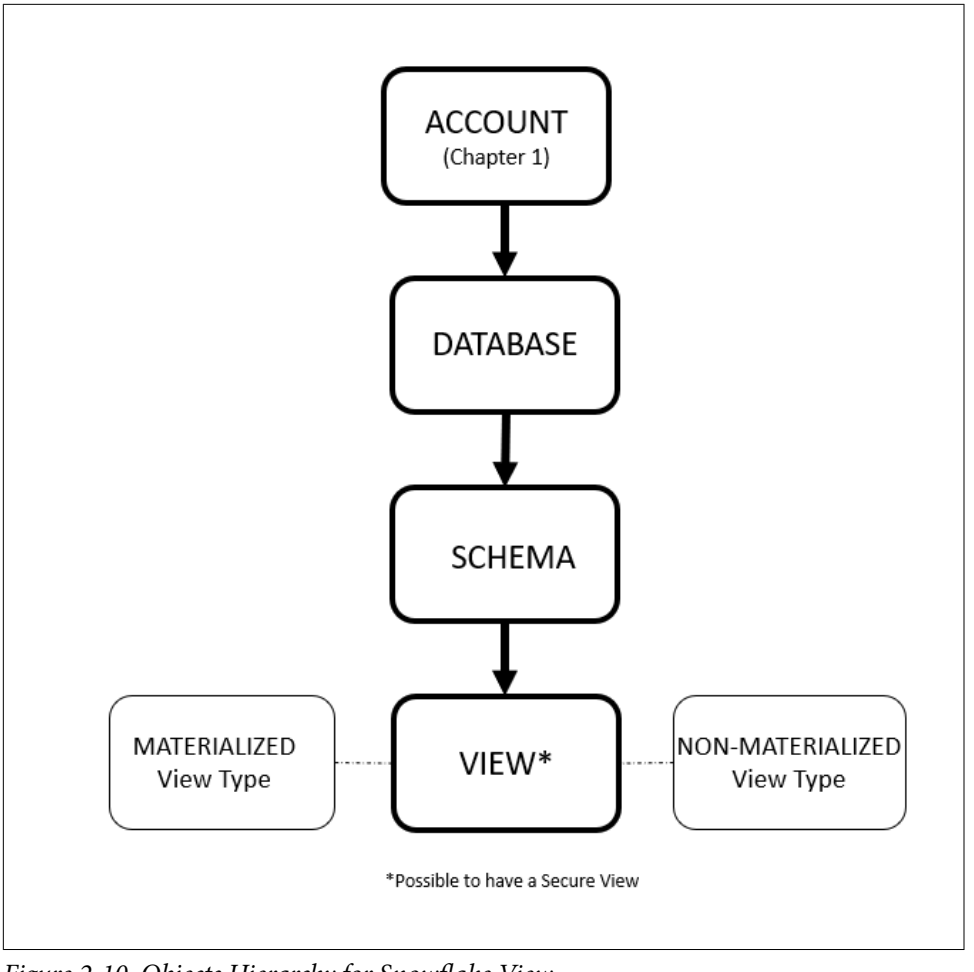



*Figure 2-10. Objects Hierarchy for Snowflake View*

A *view* is considered to be a virtual table created by a query expression; something like a window into a database. Let's create a new view by selecting one column from the Snowflake sample data.

We've mentioned the importance of using fully qualified names for tables. The importance of using a fully qualified name for the table is even more important when creating views because the connected reference will be invalid if the namespace of the base table is not used and this table or the view is moved to a different schema or database later.

```
CREATE
OR REPLACE VIEW CHAPTER3_TDB1.PUBLIC.NEWVIEW AS
SELECT
    CC_NAME
FROM
    (
        SELECT
            *
        FROM
            SNOWFLAKE_SAMPLE_DATA.TPCDS_SF100TCL.CALL_CENTER
    );
```

One purpose of views is to display selected rows and columns from one or more tables. This is a way to provide some security by only exposing certain data to specific users. There is the ability for views to provide even more security by creating a specific *secure view* of either a non-materialized or materialized view. We'll dive deeper into secure views when we discuss implementing account security and protections in Chapter 7. We'll also learn more about secure views in Chapter 10, Configuring and managing secure data sharing.

It's important to remember that creating materialized views require Snowflake Enterprise Edition. Let's create a materialized view using the same query as before.

```
CREATE
OR REPLACE MATERIALIZED VIEW CHAPTER3_TDB1.PUBLIC.NEWVIEW_MATERIALIZED AS
SELECT
    CC_NAME
FROM
    (
        SELECT
            *
        FROM
            SNOWFLAKE_SAMPLE_DATA.TPCDS_SF100TCL.CALL_CENTER
    );
```

You can run a "SHOW VIEWS" command and both views will be returned in the results. If you run a "SHOW MATERIALIZED VIEWS" command, then only the materialized view result will be returned.

If you run a SELECT * command for each of the views, you'll notice that the results are identical. That is because we haven't really used a materialized view for its intended purpose. Unlike a regular view, a materialized view object gets periodically refreshed with the data from the base table. Thus, it is illogical to consider using a materialized view for the Snowflake sample database because the Snowflake sample database cannot be updated with new data.

Also, the query to retrieve a single column is not one typically used for materialized views. Materialized views are generally used to aggregate as well as filter data so that the results of resource-intensive operations can be stored in a materialized view for

improved data performance. Improved data performance is especially good when that same query is frequently used.

The data within a materialized view is always current because Snowflake uses a background service to automatically update materialized views. To see that in action, we're going to create a materialized view. We will revisit the view later in the chapter.

```
CREATE
OR REPLACE MATERIALIZED VIEW CHAPTER3_TDB1.PUBLIC.BANKINGVIEW_MV AS
SELECT
    *
FROM
    (
        SELECT
            *
        FROM
            CHAPTER3_TDB1.PUBLIC.SUMMARY
    );
```

As you would expect, views are read-only. Thus, it isn't possible to use the INSERT, UPDATE, or DELETE commands on views. Further, Snowflake doesn't allow users to truncate views. While it is not possible to execute DML commands on a view, you can use a subquery within a DML statement that can be used to update the underlying base table. An example might be something like:

```
DELETE FROM <Base Table> WHERE <Column> > (SELECT AVG <Column> FROM View);
```

Other things to be aware of is that a view definition cannot be updated with the ALTER VIEW command. However, the ALTER MATERIALIZED VIEW command can be used to rename a materialized view, to add or replace comments, to modify the view to be a secure view, and much more. The SHOW and DESCRIBE commands are also available for views.

If you wanted to change something structural about the view, you would have to recreate it with a new definition.

Changes to a source table's structure do not automatically propagate to views. For example, dropping a table column won't drop the column in the view.

There are many considerations when deciding between a regular view and a materialized view. Other considerations beyond whether to create a view or a materialized view is considering whether to use ETL to materialize the data set in a table.

As a general rule, it is best to use a non-materialized view when the results of the view frequently change, the query isn't so complex and expensive to rerun, and the results

of the view often change. Regular views do incur compute costs but not storage costs. The compute cost to refresh the view and the storage cost will need to be weighed against the benefits of a materialized view when the results of a view change often.

Generally, it is beneficial to use a materialized view when the query consumes a lot of resources as well as when the results of the view are used often and the underlying table doesn't change frequently. Also, if a table needs to be clustered multiple ways, a materialized view can be used with a cluster key.

There are some limitations for materialized views, such as a materialized view can query only a single table and joins are not supported. It is recommended that you consult the Snowflake documentation for more detail on materialized view limitations.

One thing to remember is that we are using the SYSADMIN role currently and we're creating the views using that role. For someone who doesn't have the SYSDAMIN role, they will need to have assigned to them the privileges on the schema, the database objects in the underlying table(s), and the view itself if they are to work with the view.

## Introduction to Snowflake Stages - File Format Included

There are two types of Snowflake stages: internal and external. Stages are Snowflake objects that point to a storage location, either internal to Snowflake or on external cloud storage. Stage objects can be "named stages" or internal user or table stages. The "temporary" keyword can be used to create a session-based name stage object.

In most cases, the storage is permanent while the stage object, a pointer to the storage location, may be temporary or dropped at any time. Snowflake stages are often used as an intermediate step to load files to Snowflake tables or to unload data from Snowflake tables into files.

Snowflake permanent and internal temporary stages are used to store data files internally, on cloud storage managed by Snowflake whereas external stages reference data files that are stored in a location outside of Snowflake. Outside locations, whether private / protected, or public, like Amazon S3 buckets, Google Cloud Storage buckets, and Microsoft Azure containers, are supported by Snowflake and can be used in external stages.

Each Snowflake user has a stage for storing files which is accessible only by that user. The User stage can be referenced by @~. Likewise, each Snowflake table has a stage allocated for storing files and can be referenced by using @%<*name of table*>.

Table stages are useful if multiple users need to access the files and those files only need to be copied into a single table whereas a user stage is best when the files only need to be accessed by one user but will need to be copied into multiple tables. [end note]

User and table stages cannot be altered or dropped and neither of these stages support setting the file format, but you can specify the format and copy options at the time the "COPY INTO" command is issued. Additionally, table stages do not support transforming the data while loading it. A table stage is tied to the table itself and is not a separate database object. To perform actions on the table stage, you must have been granted the table ownership role.

The command to list a user stage is ls@~; or LIST @~; . Figure 2-11 shows the results of the command to list a user stage.

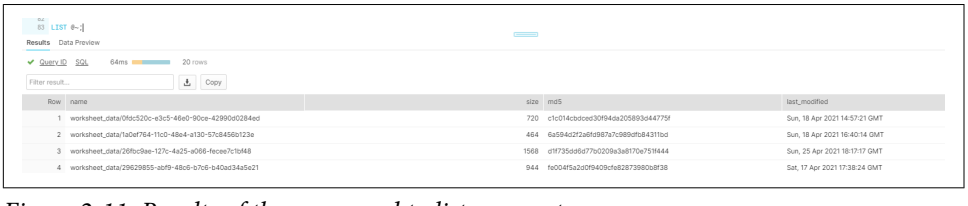



*Figure 2-11. Results of the command to list a user stage*

User stages and table stages, both of which are types of internal stages, are automatically provided for each Snowflake account. In addition to user and table stages, internal named stages can also be created (see Figure 2-12). Internal named stages are database objects, which means that they can be used not just by one user but by any user who has been granted a role with the appropriate privileges.

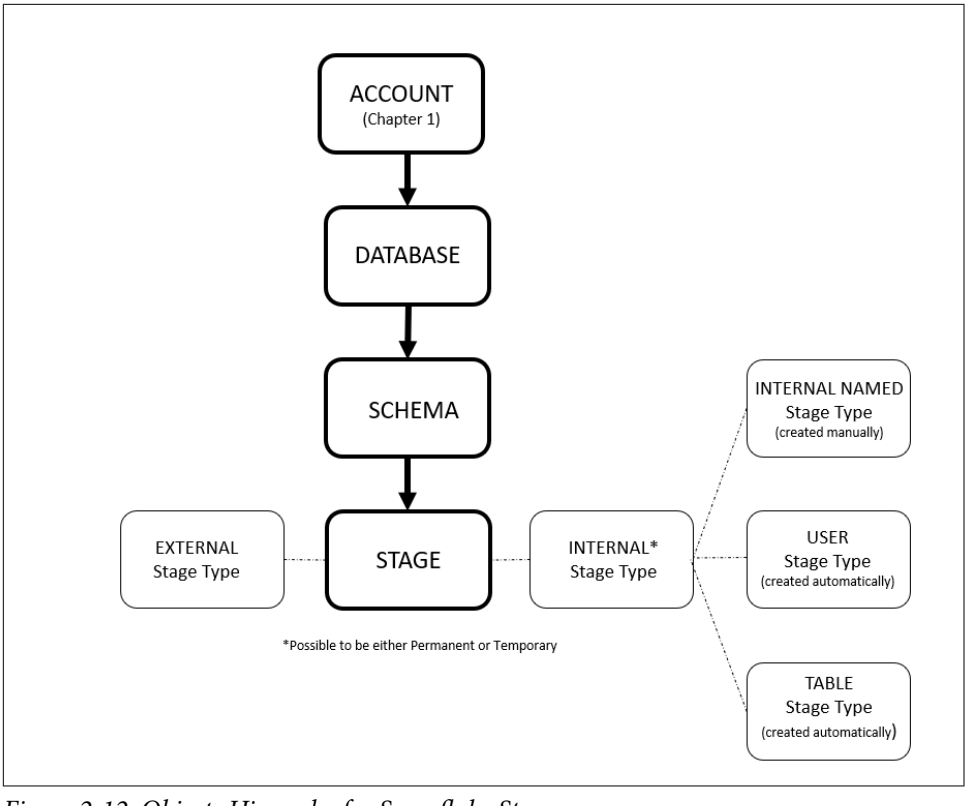



*Figure 2-12. Objects Hierarchy for Snowflake Stage*

Internal named stages and external stages can be created as either a permanent or a temporary stage. When a temporary external stage is dropped, no data files are removed because those files are stored external to Snowflake. Only the stage object is dropped. For a temporary internal stage, however, the data and stage are both dropped; and the files are not recoverable. It is important to note that the behavior just described is not limited to just temporary stage objects. Both temporary and permanent stages, internal or external, have the same characteristics described.

When using stages, we can use file formats to store all the format information we need for loading data from files to tables. The default file format is CSV. However, you can create file formats for other formats such as JSON, AVRO, ORC, PARQUET, and XML. There are also optional parameters that can be included when you create a file format. We are going to create a file format for loading JSON data. Then, we'll make use of that file format when we create a stage.

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_TDB1;
CREATE
OR REPLACE FILE FORMAT JSON_FILEFORMAT TYPE = JSON;
```

```
USE DATABASE CHAPTER3_TDB1;
USE SCHEMA PUBLIC;
CREATE
OR REPLACE TEMPORARY STAGE TEMP_STAGE FILE_FORMAT = JSON_FILEFORMAT;
```

The data is always in an encrypted state, whether data is in flight between the customer and internal stage or at rest and stored in a Snowflake database table.

File formats have been briefly introduced here and will be explored much more in Chapter 6, Data Loading and Unloading.

## Extending SQL with Stored Procedures and UDFs

To extend SQL capabilities in Snowflake, you can create stored procedures and user defined functions (UDFs) to achieve functionalities not possible with Snowflake built-in functions. Both stored procedures and UDFs encapsulate and return a single value (scalar). UDTFs can return multiple values (tabular) whereas stored procedures can return only a single value. You can create stored functions in JavaScript and UDFs in both SQL and JavaScript languages. It is possible to create secure UDFs (see Figure 2-13).

The return value for stored procedures is scalar but procedures can return multiple values if the return type is a variant.

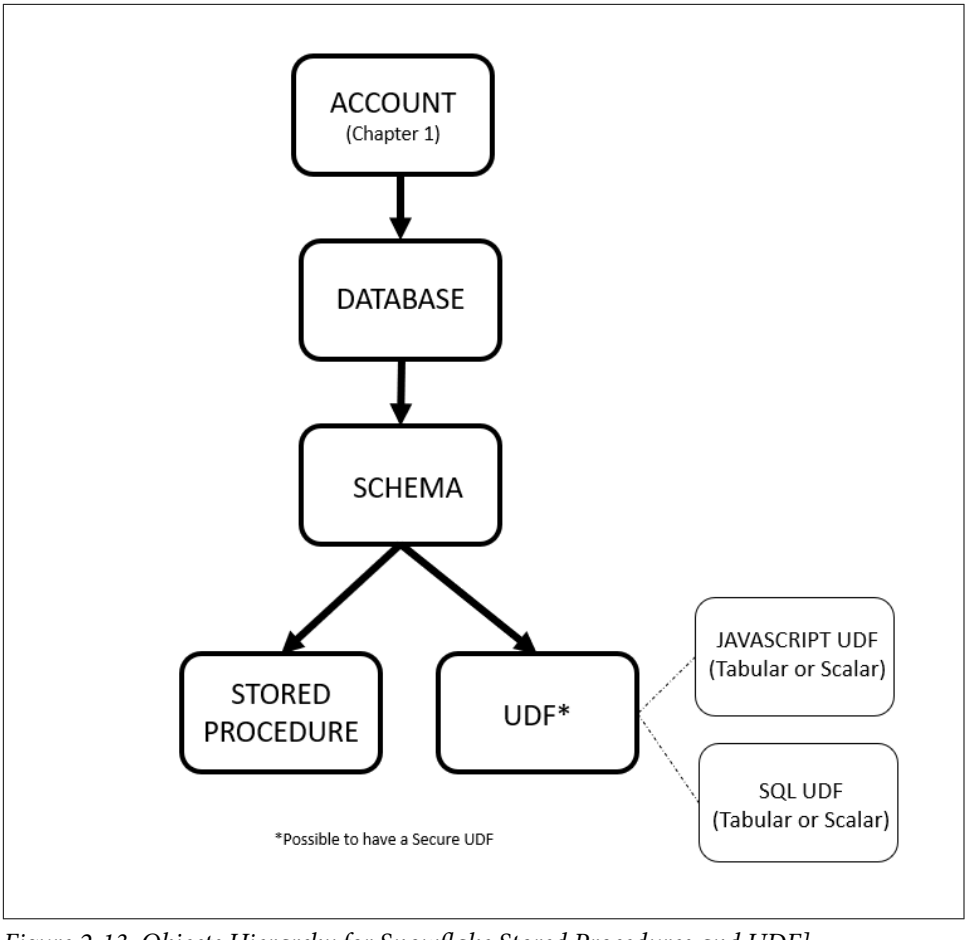



*Figure 2-13. Objects Hierarchy for Snowflake Stored Procedures and UDF]*

Both stored procedures and UDFs extend SQL capabilities but there are many differences between the two. One of the most important differences is how they are used.

If you need to perform database operations such as SELECT, DELETE, or CREATE, you'll need to use a stored procedure. If you want to use a function as part of the SQL statement or expression or if your output needs to include a value for every input row, then you'll want to use a Snowflake UDF.

A UDF is called as part of the SQL statement, but a stored procedure cannot be called within a SQL statement. Instead, a stored procedure is called as an independent statement using the "CALL" statement. The "CALL" statement can call only one stored procedure per statement.

A UDF is required to return a value and you can use the UDF return value inside your SQL statements. Although not required, a stored procedure is allowed to return a value, but the "CALL" command doesn't provide a place to store the returned value. The stored procedure also doesn't provide a way to pass it to another operation.

In the next two sections, there are a total of five examples provided. The first is a simple JavaScript UDF that returns a scalar value and the next is a secure SQL UDF that returns tabular results. Following those are three stored procedures examples. The first is where an argument is directly passed in. The next example is lengthier and demonstrates the basics of an Accounting Information System where each banking transaction has a debit and credit entry. The last example is an advanced example that combines a stored procedure with a task.

## User Defined Function (UDF) – Task Included

UDFs allow you to perform some operations that are not available through the built-in, system-defined functions provided by Snowflake. There are two languages for UDFs supported by Snowflake. Both SQL and JavaScript can return either scalar or tabular results.

A SQL UDF evaluates SQL statements and it can refer to other UDFs, although a SQL UDF cannot refer to itself either directly or indirectly.

A JavaScript UDF is useful for manipulating variant and JSON data. A JavaScript UDF expression can refer to itself recursively, although it cannot refer to other UDFs. JavaScript UDFs also have size and depth limitations that don't apply to SQL UDFs. We'll see that demonstrated in one of our examples.

JavaScript UDFs have access to the basic standard JavaScript library needed to create arrays, variables, and simple objects. You cannot use math functions or use error handling because Snowflake does not let you import external libraries. The properties that are available for both JavaScript UDFs and JavaScript Procedures can be found by using the commands below.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE DATABASE DB_CHAPTER3;
USE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE FUNCTION JS_PROPERTIES() RETURNS string LANGUAGE JAVASCRIPT AS $$
        return Object.getOwnPropertyNames(this);
    $$;
SELECT
    JS_PROPERTIES();
```

For our first UDF example, we are going to create a simple JavaScript UDF which returns a scalar result. We mentioned that JavaScript UDFs have size and depth limitations and we'll be able to demonstrate that in this example.

```
USE ROLE SYSADMIN;
USE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE FUNCTION FACTORIAL(n variant) RETURNS variant LANGUAGE JAVASCRIPT AS '
     var f=n;
     for (i=n-1; i>0; i--) {
  f=f*i
    }
 return f';
SELECT
    FACTORIAL(5);
```

The result returned is 120 when the number 5 is used. If you use a number greater than 33, you'll receive an error message. Try finding the result of FACTORIAL(50) and see what happens.

Secure UDFs are the same as non-secure UDFs except that they hide the DDL from the consumer of the UDF. Secure UDFs do have limitations on performance functionality due to some optimizations being bypassed. Thus, data privacy versus performance are the considerations because only secure UDFs can be shared. Secure SQL UDFs and JavaScript secure UDFs are both shareable but operate differently and are generally used for different purposes.

JavaScript secure UDFs are often used for data cleansing, address matching, or other data manipulation operations.

Unlike JavaScript secure UDFs, a secure SQL UDF can run queries. For a secure shared UDF, the queries can only be run against the provider's data. When a provider shares a secure UDF with a customer, the cost of data storage for any tables being accessed by the function is paid for by the provider and the compute cost is paid for by the consumer. There may be shared functions that don't incur storage costs.

In this example created for you, there will be no data storage cost incurred because we are using the Snowflake sample data set.

## Secure SQL UDTF That Returns Tabular Value (Market Basket Analysis Example)

Market basket analysis is a common use of secure SQL UDFs and that is what we'll be demonstrating. In our example, the output is aggregated data where a consumer would like to see how many times other items were sold with their particular individual item. We wouldn't want the consumer account to have access to our raw sales data, so we'll wrap the SQL statement in a secure UDF and create an input parameter.

Using the secure UDF with an input parameter, the consumer still gets the same results as running the SQL statement directly on the underlying raw data.

We want to use data that is already provided for us in the Snowflake sample database but there are more records than we need for this demonstration. Let's create a new table and select 100,000 rows from the sample database. That will be more than enough.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE DATABASE DB_UDF;
CREATE
OR REPLACE SCHEMA SCHEMA1;
CREATE
OR REPLACE TABLE DB_UDF.SCHEMA1.SALES AS (
    SELECT
        *
    FROM
        "SNOWFLAKE_SAMPLE_DATA"."TPCDS_SF100TCL"."WEB_SALES"
)
LIMIT
    100000;
```

Next, we'll run our query directly on the new table. In this instance, we are interested in the product with the SK of 87. We want to know the different items that were sold with this product in the same transaction. We can use this query to find that information.

```
SELECT
    87 AS INPUT_ITEM,
    WS_WEB_SITE_SK AS BASKET_ITEM,
    COUNT (DISTINCT WS_ORDER_NUMBER) BASKETS
FROM
    DB_UDF.SCHEMA1.SALES
WHERE
    WS_ORDER_NUMBER IN (
        SELECT
            WS_ORDER_NUMBER
        FROM
            DB_UDF.SCHEMA1.SALES
        WHERE
            WS_WEB_SITE_SK = 87
    )
GROUP BY
    WS_WEB_SITE_SK
ORDER BY
    3 DESC,
    2;
```

The results of this query shows us the product with SK of 87 was sold in 152 unique transactions within our records. The item with SK of 9 and the item with SK of 72

were each sold in the same transaction as the item with SK of 87 a total of 34 times. For the manufacturers of product with SK of 9 and 72, this could be valuable information. We might be willing to share those details but we wouldn't want to allow access to the underlying sales data. Thus, we'll want to create a secure SQL UDF function.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SECURE FUNCTION DB_UDF.SCHEMA1.GET_MKTBASKET(INPUT_WEB_SITE_SK num-
ber(38)) RETURNS TABLE (
    INPUT_ITEM NUMBER(38, 0),
    BASKET_ITEM NUMBER(38, 0),
    BASKETS NUMBER(38, 0)
) AS 'SELECT input_web_site_sk, WS_WEB_SITE_SK as BASKET_ITEM, COUNT(DISTINCT
WS_ORDER_NUMBER) BASKETS
FROM DB_UDF.SCHEMA1.SALES
WHERE WS_ORDER_NUMBER IN (SELECT WS_ORDER_NUMBER FROM DB_UDF.SCHEMA1.SALES WHERE
WS_WEB_SITE_SK = input_web_site_sk)
GROUP BY ws_web_site_sk
ORDER BY 3 DESC, 2';
```

If we were to share with another user this secure UDF through a Snowflake consumer account, that user could run the secure UDF without seeing any of the underlying data, table structures, or the SQL code. This is the command that the owner of the consumer account would use to obtain the results. You can try this command with the number 87 that we used earlier when we queried the table directly and you'll get the same exact result with the UDF function. You can also try other product SKs.

```
SELECT
    *
FROM
    TABLE(DB_UDF.SCHEMA1.GET_MKTBASKET(9));
```

Using Secure UDFs should be specifically used for instances where data privacy is of concern, and you want to limit access to sensitive data. It is important to consider the purpose and necessity of creating a secure UDF and weigh that against the decreased query performance that is likely to result from using a secure UDF.

## Stored Procedures

Stored procedures are similar to functions in that they are created once and can be executed many times. Stored procedures allow you to extend Snowflake SQL by combining it with JavaScript in order to include branching and looping, as well as error handling. Stored procedures, which must be written in JavaScript, can be used to automate tasks that require multiple SQL statements performed frequently. Although

stored procedures can only be written in JavaScript at this time, SQL stored procedures are now in private preview.

While you can "SELECT" statements inside a stored procedure, the results must be used within the stored procedure. If not, then only a single value result can be returned. Stored procedures are great for batch actions because a stored procedure runs by itself and, similar to a trigger, can be conditionally tied to database events.

In the first stored procedures example, we are going to pass in an argument to the stored procedure.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE PROCEDURE STOREDPROC1(ARGUMENT1 VARCHAR)
returns string not null
language javascript
as
$$
var INPUT_ARGUMENT1 = ARGUMENT1;
var result = `${INPUT_ARGUMENT1}`
return result;
$$;
CALL STOREDPROC1('I really love Snowflake  ');
```

Javascript is case sensitive so make sure you pay close attention when creating the stored procedure.

Figure 2-14 shows the results of the passing in an argument to the stored procedure.

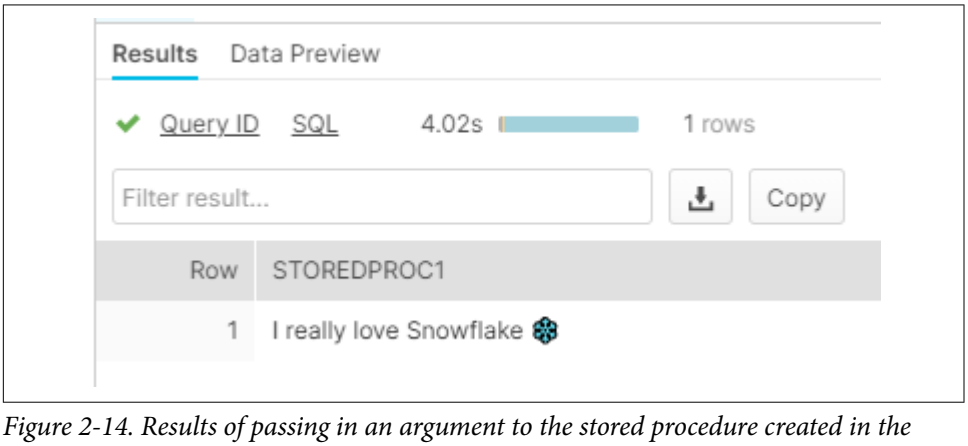



*Figure 2-14. Results of passing in an argument to the stored procedure created in the chapter*

You can use the INFORMATION_SCHEMA to take a look at the information for Snowflake Procedures in the database.

```
SELECT
    *
FROM
    "DB_CHAPTER3"."INFORMATION_SCHEMA"."PROCEDURES";
```

The next stored procedure example is one where we are demonstrating the very basics of an Accounting Information System where tabular results are returned for banking transactions that record debits and credits. If you remember, earlier in the chapter we created the tables needed for this example so we can just dive right into creating the stored procedure.

We are recording the accounting transactions for a bank that deals with customer's giving cash to the bank and getting cash from the bank. We'll keep the accounting portion of the example limited to three types of transactions – deposits, withdrawals, and loan payments.

First, we'll want to create a stored procedure for a deposit transaction where the bank's cash account is debited and the customer account on the bank's balance sheet is credited whenever a customer gives the bank cash to add to their account.

```
USE DATABASE CHAPTER3_PDB1;
USE ROLE SYSADMIN;
CREATE
OR REPLACE PROCEDURE deposit(PARAM_ACCT FLOAT, PARAM_AMT FLOAT) returns STRING LAN-
GUAGE javascript AS $$
    var ret_val = "";
    var cmd_debit = "";
    var cmd_credit = "";

    // INSERT data into tables
    cmd_debit = "INSERT INTO CHAPTER3_PDB1.BANKING.CASH VALUES (" + PARAM_ACCT +
"," + PARAM_AMT + ",current_timestamp());";
    cmd_credit = "INSERT INTO CHAPTER3_PDB1.BANKING.CUSTOMER_ACCT VALUES (" +
PARAM_ACCT + "," + PARAM_AMT + ",current_timestamp());";

    // BEGIN transaction
    snowflake.execute ({sqlText: cmd_debit});
    snowflake.execute ({sqlText: cmd_credit});
        ret_val = "Deposit Transaction Succeeded";
    return ret_val;
    $$;
```

Next, we'll create the transaction for a withdrawal. In this case, it is just the reverse of what happens for a deposit.

```
USE ROLE SYSADMIN;
CREATE OR REPLACE PROCEDURE withdrawal (PARAM_ACCT FLOAT,PARAM_AMT FLOAT)
    returns STRING
```

```
    LANGUAGE javascript
    AS
    $$
    var ret_val = "";
    var cmd_debit = "";
    var cmd_credit = "";

    // INSERT data into tables
    cmd_debit = "INSERT INTO CHAPTER3_PDB1.BANKING.CUSTOMER_ACCT VALUES (" +
PARAM_ACCT + "," + (-PARAM_AMT) + ",current_timestamp());";
    cmd_credit = "INSERT INTO CHAPTER3_PDB1.BANKING.CASH VALUES (" + PARAM_ACCT +
"," + (-PARAM_AMT) + ",current_timestamp());";

    // BEGIN transaction
    snowflake.execute ({sqlText: cmd_debit});
    snowflake.execute ({sqlText: cmd_credit});
        ret_val = "Withdrawal Transaction Succeeded";
    return ret_val;
    $$;
```

Finally, the transaction for the loan payment is one where the bank's cash account is debited and the receivables account is credit.

```
USE ROLE SYSADMIN;
CREATE OR REPLACE PROCEDURE loan_payment (PARAM_ACCT FLOAT,PARAM_AMT FLOAT)
    returns STRING
    LANGUAGE javascript
    AS
    $$
    var ret_val = "";
    var cmd_debit = "";
    var cmd_credit = "";

    // INSERT data into the tables
    cmd_debit = "INSERT INTO CHAPTER3_PDB1.BANKING.CASH VALUES (" + PARAM_ACCT +
"," + PARAM_AMT + ",current_timestamp());";
    cmd_credit = "INSERT INTO CHAPTER3_PDB1.BANKING.RECEIVABLES VALUES (" +
PARAM_ACCT + "," + (-PARAM_AMT) + ",current_timestamp());";
    //BEGIN transaction
    snowflake.execute ({sqlText: cmd_debit});
    snowflake.execute ({sqlText: cmd_credit});
        ret_val = "Loan Payment Transaction Succeeded";
    return ret_val;
    $$;
```

Now, let's run a few quick tests to see if the procedures are working.

```
CALL withdrawal(21, 100);
CALL loan_payment(21, 100);
CALL deposit(21, 100);
```

We can tell that the procedures are working if we run some SELECT commands. For example:

```
SELECT CUSTOMER_ACCOUNT, AMOUNT FROM "CHAPTER3_PDB1"."BANKING"."CASH";
```

After using the "CALL" command followed by the SELECT command to test a few transactions, we feel confident that the procedure is working as intended.

So now we can truncate the tables, leaving the tables intact but removing the data.

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_PDB1;
USE SCHEMA BANKING;
TRUNCATE TABLE "CHAPTER3_PDB1"."BANKING"."CUSTOMER_ACCT";
TRUNCATE TABLE "CHAPTER3_PDB1"."BANKING"."CASH";
TRUNCATE TABLE "CHAPTER3_PDB1"."BANKING"."RECEIVABLES";
```

Note that if we run the previous SELECT statements again now, we'll be able to see that there is no data in the tables. Now, we'll go ahead and input some transactions.

```
USE ROLE SYSADMIN;
CALL deposit(21, 10000);
CALL deposit(21, 400);
CALL loan_payment(14, 1000);
CALL withdrawal(21, 500);
CALL deposit(72, 4000);
CALL withdrawal(21, 250);
```

We'd like to see a transaction summary, so we'll create one final stored procedure.

```
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_TDB1;
USE SCHEMA PUBLIC;
CREATE OR REPLACE PROCEDURE Transactions_Summary()
    returns STRING
    LANGUAGE javascript
    AS
    $$
    var cmd_truncate = `TRUNCATE TABLE IF EXISTS CHAPTER3_TDB1.PUBLIC.SUMMARY;`
    var sql = snowflake.createStatement({sqlText: cmd_truncate});
    var cmd_cash = `Insert into CHAPTER3_TDB1.PUBLIC.SUMMARY (CASH_AMT) select
sum(AMOUNT) from "CHAPTER3_PDB1"."BANKING"."CASH";`
    var sql = snowflake.createStatement({sqlText: cmd_cash});
    var cmd_receivables = `Insert into CHAPTER3_TDB1.PUBLIC.SUMMARY (RECEIVA-
BLES_AMT) select sum(AMOUNT) from "CHAPTER3_PDB1"."BANKING"."RECEIVABLES";`
    var sql = snowflake.createStatement({sqlText: cmd_receivables});
    var cmd_customer = `Insert into CHAPTER3_TDB1.PUBLIC.SUMMARY (CUSTOMER_AMT)
select sum(AMOUNT) from "CHAPTER3_PDB1"."BANKING"."CUSTOMER_ACCT";`
    var sql = snowflake.createStatement({sqlText: cmd_customer});


    //BEGIN transaction
        snowflake.execute ({sqlText: cmd_truncate});
```

```
        snowflake.execute ({sqlText: cmd_cash});
        snowflake.execute ({sqlText: cmd_receivables});
        snowflake.execute ({sqlText: cmd_customer});
        ret_val = "Transactions Successfully Summarized";
        return ret_val;
     $$;
```

Now, we can see the Transaction Summary. We'll call the stored procedure so that all the debit and credit transactions are summarized and then we'll take a look at the table.

```
CALL Transactions_Summary();

SELECT
    *
FROM
    CHAPTER3_TDB1.PUBLIC.SUMMARY;

Let's also take a look now at the materialized view we created earlier.
USE ROLE SYSADMIN;
USE DATABASE CHAPTER3_TDB1;
USE SCHEMA PUBLIC;
SELECT
    *
FROM
    "CHAPTER3_TDB1"."PUBLIC"."BANKINGVIEW_MV";
```

Now, we have our final stored procedural example. It's an advanced example because we are going to add a task to execute this stored procedure.

Just a quick side note here. Tasks are incredibly powerful and an important topic. We'll cover tasks in more detail in chapter 12 as we see how tasks can be combined with table streams. For now, it's enough to understand that a task can call a stored procedure, as we are going to see in this example, or it can execute a single SQL statement.

We will be creating a stored procedure that will delete a database. Thus, it's important that we create the stored procedure in a different database than the one we'll want to delete using the stored procedure.

```
USE ROLE SYSADMIN;
USE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE PROCEDURE drop_db() RETURNS STRING NOT NULL LANGUAGE javascript AS $$
    var cmd = `DROP DATABASE "CHAPTER3_PDB1";`
    var sql = snowflake.createStatement({sqlText: cmd});
    var result = sql.execute();
    return 'Database has been successfully dropped';
    $$;
```

Now we can call the stored procedure and the database will be dropped. This is part of our cleanup for this chapter.

```
CALL drop_db();
```

Now that you've seen how this stored procedure works, we'll modify it so that it will drop a different database, and we'll add a task so that the database will be dropped 15 minutes later. That way you can see how a task works.

Let's go ahead and change our drop_db procedure so that we'll be dropping the database CHAPTER3_TDB1.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE PROCEDURE drop_db() RETURNS STRING NOT NULL LANGUAGE javascript AS $$
    var cmd = `DROP DATABASE "CHAPTER3_TDB1";`
    var sql = snowflake.createStatement({sqlText: cmd});
    var result = sql.execute();
    return 'Database has been successfully dropped';
    $$;
```

Next, we'll want to create the task that will delay the stored procedure by 15 minutes.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE TASK wait_15_task WAREHOUSE = COMPUTE_WH SCHEDULE = '15 MINUTE' AS CALL
drop_db();
```

The SYSADMIN role is going to need some privileges to execute the task so be sure to use the ACCOUNTADMIN role for this command. Even though the SYSADMIN role is the task owner, an elevated account level privilege to execute tasks is required.

```
USE ROLE ACCOUNTADMIN;
GRANT EXECUTE TASK ON ACCOUNT TO ROLE SYSADMIN;
```

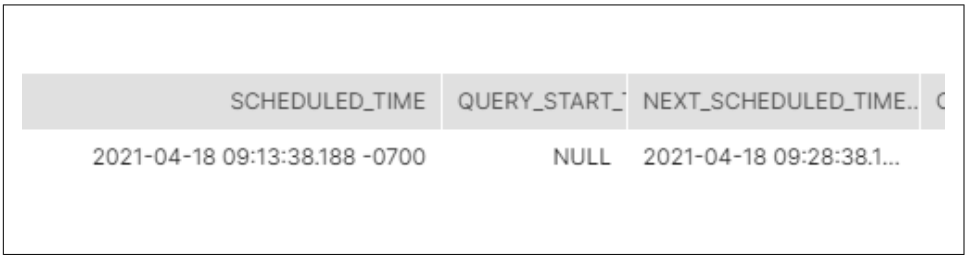
Because tasks are always created in a suspended state, they'll need to be resumed.

```
USE ROLE SYSADMIN;
ALTER TASK IF EXISTS wait_15_task RESUME;
```

Now our task is in a scheduled state. We'll be able to see that by using this query against the INFORMATION_SCHEMA TASK_HISTORY table function.

```
SELECT
    *
FROM
    table(
        information_schema.task_history(
            task_name => 'wait_15_task',
            scheduled_time_range_start => dateadd('hour', -1, current_timestamp())
        )
    );
```

Figure 2-15 shows the results of the query.



| SCHEDULED_TIME | QUERY_START_T | NEXT_SCHEDULED_TIME.. | C |
|---|---|---|---|
| 2021-04-18 09:13:38.188 -0700 | NULL | 2021-04-18 09:28:38.1... | |

*Figure 2-15. Query results to see the current status of the task named "wait_15_task"*

You can use the next 15 minutes to answer the questions at the end of the chapter to test your knowledge and then come back. Once you see that the task has been completed and the database has been dropped (you can refresh your screen, or you can run the query again to see the state of the task) then you can suspend the task.

```
USE ROLE SYSADMIN;
ALTER TASK IF EXISTS wait_15_task SUSPEND;
```

After you suspend the task, you can run the query one last time and you'll see that the task succeeded and that there are no tasks scheduled.

There is so much more to explore than we can cover in this chapter! But, don't worry, you'll learn more about stored procedures, Java/Python UDFs, external functions, and Snowpark in Chapter 12.

## Introduction to Pipes, Streams, and Sequences

Pipes, streams, and sequences are Snowflake objects we've not yet covered. *Pipes* are objects that contain a "COPY" statement that is used by Snowpipe. Snowpipe is used for continuous, serverless loading of data into a Snowflake target table. Snowflake table *streams*, aka change data capture (CDC), keep track of certain changes made to a table including inserts, updates, and deletes. Streams have many useful purposes including recording changes made in a staging table which are used to update another table.

A *sequence* object is used to generate unique numbers. Often, sequences are used as surrogate keys for primary key values. Here is how you can generate a sequence that begins with the number one and increments by one.

```
USE ROLE SYSADMIN;
USE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE SEQUENCE SEQ_01 START = 1 INCREMENT = 1;
CREATE
OR REPLACE TABLE SEQUENCE_TEST_TABLE(i integer);
```

You can use the select command three or four times to see how the NEXTVAL increments by one every time.

```
SELECT
    SEQ_01.NEXTVAL;
```

What happens when you try this?

```
USE ROLE SYSADMIN;
USE DATABASE DB_CHAPTER3;
CREATE
OR REPLACE SEQUENCE SEQ_02 START = 1 INCREMENT = 2;
CREATE
OR REPLACE TABLE SEQUENCE_TEST_TABLE(i integer);
SELECT
    SEQ_02.NEXTVAL a,
    SEQ_02.NEXTVAL b,
    SEQ_02.NEXTVAL c,
    SEQ_02.NEXTVAL d;
```

You should see that the value of A is 1, the value of B is 3, the value of C is 5 and the value of D is 7.

Some important things to remember about is that the first value in a sequence cannot be changed after the sequence is created and sequence values, although unique, are not necessarily gap-free. Because sequences are user-defined database objects, the sequence value can be shared by multiple tables because sequences are not tied to any specific table. An alternative to creating a sequence is to use identity columns where you would generate auto-incrementing numbers, often used as a primary key, in one specific table.

A consideration when using sequences is that they may not be appropriate for situations such as a secure UDF case. The reason is that, in some circumstances a consumer may be able to use the difference between sequence numbers to infer information about the number of records. In that case, one option is to exclude the sequence column from the consumer results or to use a unique string ID instead of a sequence.

We'll explore Snowpipe in Chapter 6, Data Loading and Unloading. Streams will be discussed in-depth in Chapter 12 as we discover how to use streams for change data capture. We'll also see how to combine the power of streams and tasks in Chapter 12.

# Code Cleanup

Let's perform a code cleanup to remove the objects in your Snowflake account in preparation for working on another chapter example.

Note that there is no need to drop objects in the hierarchy below the database before dropping the databases. If you've been following along, you dropped all databases except DB_CHAPTER3 so you'll just need to drop that database now.

## Exercises to Test Your Knowledge

The following exercises are based on the coverage in this chapter about databases and database objects such as schemas, tables, views, stages, stored procedures and UDFs.

1. What are the different types of databases, schemas, and tables that can be created? If a particular type is not specifically stated at the time of creation, what is the default type for each?
2. What is the difference between scalar and tablular UDFs?
3. What kinds of things can you do with a stored procedure that you cannot do with a UDF?
4. What would happen if we used the "CREATE DATABASE" command and the database we want to create already exists? What if we used the "CREATE OR REPLACE DATABASE" command?
5. What is the default retention time for a database? Can the database retention time be changed? Can the database default retention time be changed?
6. Why might you choose to use the "TRUNCATE TABLE" command rather than the "DROP TABLE" command?
7. Are there any storage or compute costs associated with views?
8. What is the difference between a *fully* and a *partially qualified name*?
9. When using stages, what is the default file format? What other file formats does Snowflake support?
10. What is unique about the SNOWFLAKE database that comes with every Snowflake account?

Solutions to these exercises are available in Appendix A.

CHAPTER 3

# Exploring Snowflake SQL Commands, Data Types, and Functions

## A Note for Early Release Readers

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

This will be the 4th chapter of the final book.

If you have comments about how we might improve the content and/or examples in this book, or if you notice missing material within this chapter, please reach out to the editor at *mcronin@oreilly.com*.

The standard programming language for relational database management is the Structured Query Language (SQL). In addition to SQL support for structured data, Snowflake offers native support for semi-structured data formats such as JSON and XML. Snowflake support for unstructured data is available as well.

The main focus of this chapter is on learning the fundamentals of how to use Snowflake worksheets to execute SQL commands. Other than using worksheets in the Snowflake web UI, it is possible to use a Snowflake-native command line client, known as SnowSQL, to create and execute SQL commands. More detail about SnowSQL will be provided in future chapters.

Besides connecting to Snowflake via the web UI or SnowSQL, you can use ODBC and JDBC drivers to access Snowflake data through external applications such as Tableau and Looker. We'll explore connections to Tableau and Looker in Chapter 11. Native

connectors such as Python or Spark can also be used to develop applications for connecting to Snowflake.

In Chapter 12, we'll take a deep dive into Snowpark and learn how to query and process data in a pipeline. To help you prepare for mastering advanced topics in the upcoming chapters, we'll want to focus first on learning the basics of Snowflake SQL commands, data types, and Snowflake functions.

## Working with SQL Commands in Snowflake

The Structured Query Language (SQL) can be divided into five different language command types. To create Snowflake objects, you need to use Data Definition Language (DDL) commands. Giving access to those objects requires the Data Control Language (DCL). Next, you'll use Data Manipulation Language (DML) commands to manipulate the data into and out of Snowflake. Transaction Control Language (TCL) commands enable you to manage transaction blocks. Data Query Language (DQL) statements are then used to actually query the data. Included below is a list of common SQL commands, by type.

- Data Definition Language (DDL) commands
  - — CREATE
  - — ALTER
  - — TRUNCATE
  - — RENAME
  - — DROP
  - — DESCRIBE
  - — SHOW
  - — USE
  - — SET / UNSET
  - — COMMENT
- Data Control Language (DCL) commands
  - — GRANT
  - — REVOKE
- Data Manipulation Language (DML) commands
  - — INSERT
  - — MERGE
  - — UPDATE

  - — DELETE
  - — COPY INTO
  - — PUT
  - — GET
  - — LIST
  - — VALIDATE
  - — REMOVE
- Transaction Control Language (TCL)
  - — BEGIN
  - — COMMIT
  - — ROLLBACK
  - — CREATE
- Data Query Language (DQL)
  - — SELECT

Each of these five different command language types, and their associated commands, will be discussed briefly in the following sections. A comprehensive list of all Snowflake SQL commands can be found in the Snowflake online documentation at https://docs.snowflake.com/en/sql-reference/sql-all.html.

## Data Definition Language (DDL) Commands

Data Definition Language (DDL) commands are the SQL commands used to define the database schema. The commands create, modify, and delete database structures. In addition, DDL commands can be used to perform account-level session operations, such as setting parameters, as we'll see later in the chapter when we discuss the SET / UNSET command. DDL Commands include CREATE, ALTER, TRUNCATE, RENAME, DROP, DESCRIBE, SHOW, USE, and COMMENT. With the exception of the COMMENT command, each DDL command takes an object type and identifier.

Snowflake DDL commands manipulate objects such as databases, virtual warehouses, schemas, tables, and views; however, they do not manipulate data. Chapter 3, *Creating and Managing Snowflake Architecture Objects*, is entirely devoted to demonstrating Snowflake DDL commands with in-depth explanations and many hands-on examples.

## Data Control Language (DCL) Commands

Data Control Language (DCL) commands are the SQL commands used to enable access control. Examples of DCL commands include GRANT and REVOKE. Chapter

5, *Leveraging Snowflake Access Controls,* will take you through a complete detailed series of examples using DCL commands to show you how to secure Snowflake objects.

## Data Manipulation Language (DML) Commands

Data Manipulation Language (DML) commands are the SQL commands used to manipulate the data. The traditional DML commands such as INSERT, MERGE, UPDATE, and DELETE, exist to be used for general data manipulation. For data loading and unloading, Snowflake provides COPY INTO <table> and COPY INTO <location> commands. Additionally, Snowflake's DML commands include some commands that do not perform any actual data manipulation but are used to stage and manage files stored in Snowflake locations. Some examples include VALIDATE, PUT, GET, LIST, and REMOVE. Chapter 6, *Data Loading and Unloading*, will explore many of Snowflake's DML commands.

## Transaction Control Language (TCL) Commands

Transaction Control Language (TCL) commands are the SQL commands used to manage transaction blocks within Snowflake. Commands, such as BEGIN, COMMIT, and ROLLBACK can be used for multi-statement transactions in a session. A Snowflake transaction is a set of read and write SQL statements that are processed together as one unit. By default and upon query success, a DML statement that is run separately will be committed individually or will be rolled back at the end of the statement, if the query fails.

## Data Query Language (DQL) Commands

The Data Query Language (DQL) command is the SQL command used as either a statement or a clause to retrieve data that meet the criteria specified in the SELECT command. Note that the SELECT command is the only DQL command and it is used to retrieve data and does so by specifying the location and then using the WHERE statement to include attributes necessary for data selection inclusion.

Snowflake SELECT command works on external tables and can be used to query historical data. In certain situations, using the SELECT statement will not require a running virtual warehouse to return results; this is because of Snowflake caching, as described in Chapter 2, *Creating and Managing Snowflake Architecture*. Examples of the SELECT statement, the most common SQL statement, can be found throughout most of the chapters in this book. The following section provides details on how to make the most of the SELECT command.

# SQL Query Development, Syntax and Operators in Snowflake

Within Snowflake, SQL development can be undertaken natively, using Snowflake UI worksheets or SnowSQL, as well as via the many third-party SQL tools.

Query syntax is how Snowflake SQL queries are structured, or built. Often there are many different ways to write a SQL query that will yield the desired result. It is important to consider how to optimize the query for the best database performance and lowest cost. Chapter 9 includes a section devoted to discussing the topic of analyzing query performance and optimization techniques.

Query operators include words reserved to specify conditions in a SQL query statement and are most often used in the WHERE clause. They can also be used as conjunctions for multiple conditions in a statement. We'll explore query operators later in this section.

## SQL Development and Management

There are two native Snowflake options for developing and querying data. It is easy to get started with Snowflake SQL development using the worksheets browser-based SQL editor within the Snowflake interface. Using Snowflake worksheets requires no installation or configuration.

An alternative to worksheets would be SnowSQL, a Python-based client that can be downloaded from the Snowflake client repository and used to perform Snowflake tasks such as querying or executing DDL and DML commands. SnowSQL is frequently used for loading and unloading of data.

Snowflake provides SnowSQL versions for Linux, macOS, and Microsoft Windows. Executable SnowSQL can be run as an interactive shell or in batch mode. Snowflake provides complete instructions on how to download and install SnowSQL for all supported platforms. That documentation can be viewed at https://docs.snowflake.com/en/user-guide/snowsql-install-config.html.

You can view the recently used client versions, including the SnowSQL version, in your Snowflake account by using the Snowflake Query History. To access that information, click on the History tab, in the classic web interface. Alternatively, click on Computer > Query History if you are using the new web interface. From there, you can view the Client Info column. Interestingly, the Client Info column in the classic web interface includes an icon to indicate whether the client version is support, unsupported, or nearing the end of support (Figure 3-1)

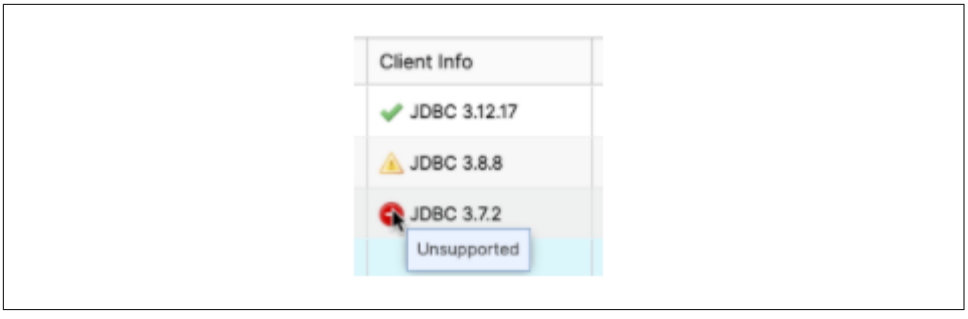



*Figure 3-1. Client Info column from the History tab (classic web interface)*

In addition to native Snowflake tools, there exists a wide variety of third-party SQL tools available for modeling, developing, and deployment SQL code in Snowflake applications. Some of these third-party tools, such as DataOps and SqlDBM, are available for a free trial by using the Snowflake Partner Connect. You can visit https://docs.snowflake.com/en/user-guide/ecosystem-editors.html for a more comprehensive list of third-party SQL tools available for use with Snowflake.

For drivers and connectors that support sending a SQL statement for preparation before execution, Snowflake will prepare DML Commands, SHOW<objects>, and SELECT SQL statements received from drivers and connectors that support that functionality. Other types of SQL statements received from drivers and connectors will be executed by Snowflake without preparation.

## Query Syntax

Snowflake SQL queries begin with either the WITH clause or the SELECT command. The WITH clause, an optional clause that precedes the SELECT statement, is used to define common table expressions (CTEs) which are referenced in the FROM clause. Most queries, however, begin with the SELECT command and syntax which appears afterward. The other syntax, described in Table 4-1, are evaluated in the following order:

- From
- Where
- Group by
- Having
- Window
- Qualify
- Order By

- Limit

*Table 3-1. Snowflake Query Syntax*

| Query Syntax | | Comments |
|---|---|---|
| WITH | | Optional clause that precedes the body of the 'SELECT' statement |
| TOP<n> | | Contains the maximum number of rows returned, recommended to include 'ORDER BY' |
| FROM | AT\|BEFORE, CHANGES, CONNECT BY, JOIN, MATCH_RECOGNIZE, PIVOT / UNPIVOT, SAMPLE / TABLESAMPLE_VALUE | Specifies the tables, views, or table functions to use in a 'SELECT' statement |
| WHERE | | Specifies a condition that matches a subset of rows; can filter the result of the 'FROM' clause; can specify which rows to operate on in an 'UPDATE', 'MERGE', or 'DELETE' |
| GROUP BY | GROUP BY CUBE, GROUP BY GROUPING SETS, GROUP BY ROLLUP, HAVING | Groups rows with the same group-by-item expressions and computes aggregate functions for resulting group; can be a column name, a number which references a position in the 'SELECT' list, or a general expression |
| QUALIFY | | Filters the results of window functions |
| ORDER BY | | Specifies an ordering of the rows of the result table from a 'SELECT' list |
| LIMIT / FETCH | | Constrains the maximum number of rows returned; recommended to include 'ORDER BY' |

Note that QUALIFY is evaluated after a Window function; QUALIFY works with Window functions much in the same way as HAVING does with the aggregate functions and GROUP BY clauses. More information about Window functions can be found later in this chapter.

### Subqueries, Derived Columns, and Common Table Expressions (CTEs)

A subquery is a query within another query and can be used to compute values that are returned in a SELECT list, grouped in a GROUP BY clause, or compared with other expressions in the WHERE or HAVING clause

A Snowflake subquery is a nested SELECT statement supported as a block in one or more of the following Snowflake SQL statements:

- CREATE TABLE AS
- SELECT
- INSERT
- INSERT INTO
- UPDATE

- DELETE

To prepare for our hands-on exercises for subqueries and derived columns, we need to create a few simple tables and insert some values into those tables. We'll create one database for this chapter. We'll also create a schema and table for our subqueries and derived column examples.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE DATABASE CH4_DB;
CREATE
OR REPLACE SCHEMA SUBQUERIES;
CREATE
OR REPLACE TABLE CH4_DB.SUBQUERIES.DERIVED (ID integer, Amt integer, Total integer);
INSERT INTO
    DERIVED (ID, Amt, Total)
VALUES
    (1, 1000, 4000),
    (2, 2000, 3500),
    (3, 3000, 9900),
    (4, 4000, 3000),
    (5, 5000, 3700),
    (6, 6000, 2222);
```

We'll need a second table in the Subqueries schema.

```
CREATE
OR REPLACE TABLE CH4_DB.SUBQUERIES.TABLE2 (ID integer, Amt integer, Total integer);
INSERT INTO
    TABLE2 (ID, Amt, Total)
VALUES
    (1, 1000, 8300),
    (2, 1001, 1900),
    (3, 3000, 4400),
    (4, 1010, 3535),
    (5, 1200, 3232),
    (6, 1000, 2222);
```

Having now created both tables, we can write an uncorrelated subquery.

```
SELECT
    ID,
    Amt
FROM
    CH4_DB.SUBQUERIES.DERIVED
WHERE
    Amt = (
        SELECT
            MAX(Amt)
        FROM
            CH4_DB.SUBQUERIES.TABLE2
    );
```

You'll notice that an uncorrelated subquery is an independent query, one where the value returned doesn't depend on any column of the outer query. An uncorrelated subquery returns a single result that is used by the outer query only once. On the other hand, a correlated subquery references one or more external columns. A correlated subquery is evaluated on each row of the outer query table and returns one result per row that is evaluated.

Let's try executing a correlated subquery now.

```
SELECT
    ID,
    Amt
FROM
    CH4_DB.SUBQUERIES.DERIVED
WHERE
    Amt = (
        SELECT
            Amt
        FROM
            CH4_DB.SUBQUERIES.TABLE2
        WHERE
            ID = ID
    );
```

We receive an error message telling us that a single-row subquery returns more than one row (Figure 3-2). This probably isn't what you expected.

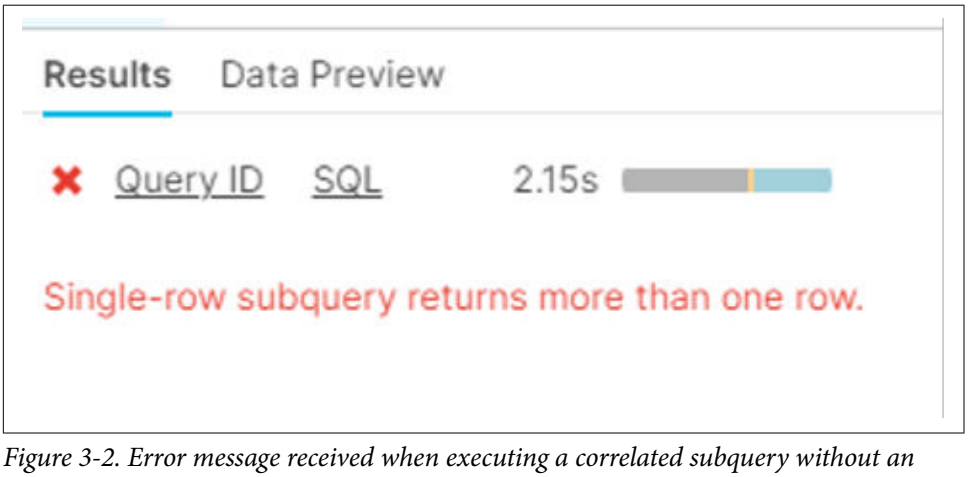



*Figure 3-2. Error message received when executing a correlated subquery without an aggregate*

Logically, we know that there is only one row per ID; so, the subquery won't be returning more than one row in the result set. However, the server can't know that. We must use a MIN, MAX, or AVG function so that the server can know for certain that only one row will be returned each time the subquery is executed.

Let's go ahead and add "MAX" to the statement to see for ourselves how this works.

```
SELECT
    ID,
    Amt
FROM
    CH4_DB.SUBQUERIES.DERIVED
WHERE
    Amt = (
        SELECT
            MAX(Amt)
        FROM
            CH4_DB.SUBQUERIES.TABLE2
        WHERE
            ID = ID
    );
```

Success! We get a result set of one row with the ID equal to the value of 3. What happens if we change the equal sign to a greater than sign?

```
 SELECT
    ID,
    Amt
FROM
    CH4_DB.SUBQUERIES.DERIVED
WHERE
    Amt > (
        SELECT
            MAX(Amt)
        FROM
            CH4_DB.SUBQUERIES.TABLE2
        WHERE
            ID = ID
    );
```

Now we get a result set with three values (Figure 3-3)

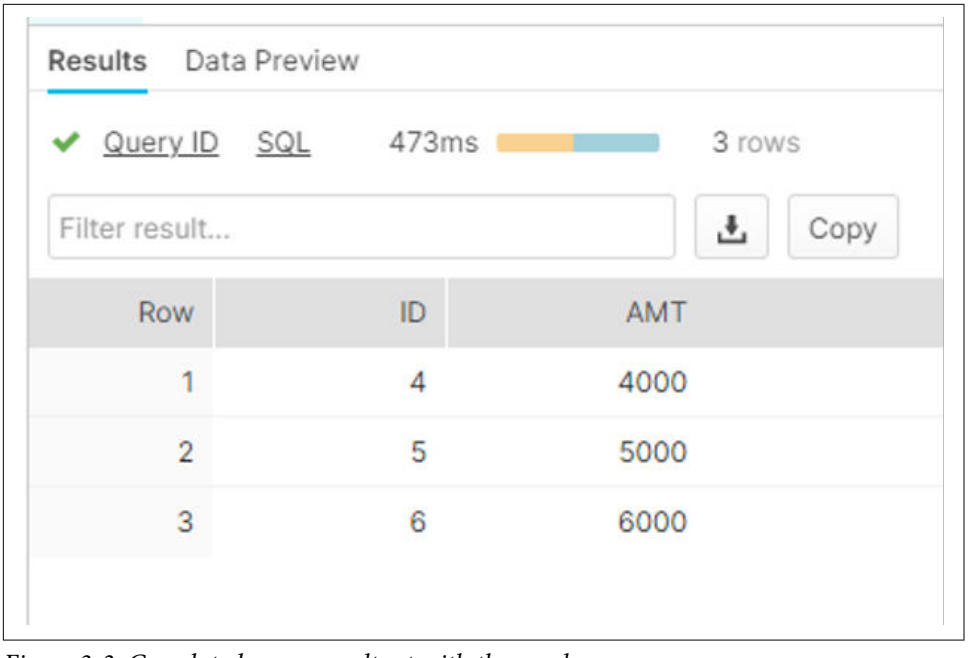



*Figure 3-3. Correlated query result set with three values*

Now what happens if we change MAX to AVG?

```
SELECT
    ID,
    Amt
FROM
    CH4_DB.SUBQUERIES.DERIVED
WHERE
    Amt > (
        SELECT
            AVG(Amt)
        FROM
            CH4_DB.SUBQUERIES.TABLE2
        WHERE
            ID = ID
    );
```

You may want to try different operators in the WHERE clause and different aggregators in the SELECT clause to see for yourself how correlated subqueries actually work.

Correlated subqueries are used infrequently because they result in one query per each row which is probably not the best scalable approach for most use cases.

Subqueries can be used for multiple purposes, one of which is to calculate or derive values which are then used in a variety of different ways. Derived columns can also be

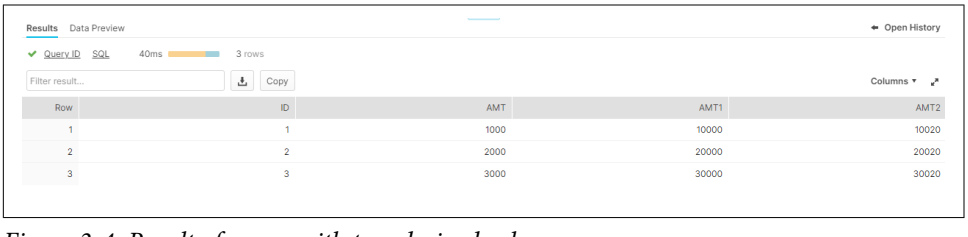
used in Snowflake to calculate another derived column, can be consumed by the outer SELECT query, or can be used as part of the WITH clause. These derived column values, sometimes called computed column values or virtual column values, are not physically stored in a table but are instead recalculated each time they are referenced in a query.

Our next example demonstrates how a derived column can be used in Snowflake to calculate another derived column. We'll also discover how we can use derived columns in one query, in subqueries, and with common table expressions.

Let's create a derived column, "Amt1", from the Amt column and then directly use the first derived column to create the second derived column, "Amt2".

```
SELECT
    ID,
    Amt,
    Amt * 10 as Amt1,
    Amt1 + 20 as Amt2
FROM
    CH4_DB.SUBQUERIES.DERIVED;
```

The result of running that query can be seen in Figure 3-4.




| Row | ID | AMT | AMT1 | AMT2 |
|---|---|---|---|---|
| 1 | 1 | 1000 | 10000 | 10020 |
| 2 | 2 | 2000 | 20000 | 20020 |
| 3 | 3 | 3000 | 30000 | 30020 |

*Figure 3-4. Result of query with two derived columns*

We can achieve the same results by creating a derived column, "Amt1", which can then be consumed by an outer SELECT query. The subquery in our example is a Snowflake uncorrelated scalar subquery. As a reminder, the subquery is considered to be an uncorrelated subquery because the value returned doesn't depend on any outer query column.

```
SELECT
    sub.ID,
    sub.Amt,
    sub.Amt1 + 20 as Amt2
FROM
    (
        SELECT
            ID,
            Amt,
            Amt * 10 as Amt1
        FROM
```

```
            CH4_DB.SUBQUERIES.DERIVED
    ) as sub;
```

Lastly, we get the same results by using a derived column as part of the WITH clause. You'll notice that we've included a common table expression (CTE) subquery which could help increase modularity and simplify maintenance. The CTE defines a temporary view name which is "CTE1" in our example. Included in the CTE are the column names and a query expression, the result of which is basically a table.

```
WITH CTE1 AS (
    SELECT
        ID,
        Amt,
        Amt * 10 as Amt2
    FROM
       CH4_DB.SUBQUERIES.DERIVED
)
SELECT
    a.ID, b.Amt,
    b.Amt2 + 20 as Amt2
FROM
    CH4_DB.SUBQUERIES.DERIVED a
    JOIN CTE1 b ON(a.ID = b.ID);
```

A major benefit of using a CTE is that it can make your code more readable. With a CTE, you can define a temporary table once and refer to it whenever you need it instead of having to declare the same subquery every place you need it. While not demonstrated here, a CTE can also be recursive. A recursive CTE can join a table to itself many times to process hierarchical data.

Whenever the same names exist for a CTE and a table or view, the CTE will take precedence. Therefore, it is recommended to always choose a unique name for your common table expressions.

### Caution about Multi-row Inserts

Now is a good time for a quick pause to learn a little more about multi-row inserts. One or more rows of data can be inserted using a select query or inserted as explicitly stated values in a comma-separated list. To keep things simple, we've been inserting values in comma-separated lists in this chapter.

There is one important thing to be aware of regarding multi-row inserts. When inserting multiple rows of data into a varchar data type, each of the data types being inserted into varchar columns must be the same or else the insert will fail. A varchar data type can accept data values such as 'one' or 1 but never both types of values in the same insert statement. We can best see this with some examples.

We'll first create a new schema and table to do some multi-row insert testing. In the first example, we'll insert 'one' into the varchar Dept column.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SCHEMA CH4_DB.TEST;
CREATE
OR REPLACE TABLE CH4_DB.TEST.TEST1 (ID integer, Dept Varchar);
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (1, 'one');
SELECT
    *
FROM
    CH4_DB.TEST.TEST1;
```

As expected, the value was successfully entered. What happens if we instead insert a numerical value into the varchar column?

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SCHEMA CH4_DB.TEST;
CREATE
OR REPLACE TABLE CH4_DB.TEST.TEST1 (ID integer, Dept Varchar);
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (1, 1);
SELECT
    *
FROM
    CH4_DB.TEST.TEST1;
```

Again, the value was successfully entered. What happens, though, if we try inserting both types into the column within the same insert statement?

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SCHEMA CH4_DB.TEST;
CREATE
OR REPLACE TABLE CH4_DB.TEST.TEST1 (ID integer, Dept Varchar);
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (1, 'one'),
    (2, 2);
```

When we try to insert two different data types into the varchar column at the same time, we experience an error, as shown in Figure 3-5.

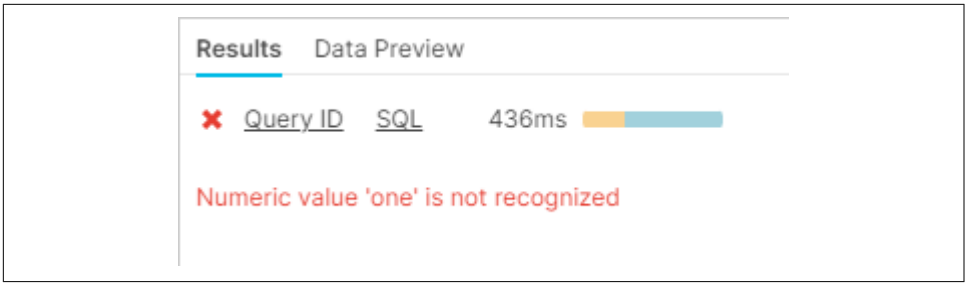



*Figure 3-5. Error message received when attempting to insert two different data types into a varchar column in one multi-row insert statement*

Let's try again but, this time, insert two values with the same data type.

```
USE ROLE SYSADMIN;
CREATE
OR REPLACE SCHEMA CH4_DB.TEST;
CREATE
OR REPLACE TABLE CH4_DB.TEST.TEST1 (ID integer, Dept Varchar);
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (1, 'one'),
    (2, 'two');
SELECT
    *
FROM
    CH4_DB.TEST.TEST1;
```

We're also successful if we insert two numerical values into the varchar column.

```
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (3, 3),
    (4, 4);
SELECT
    *
FROM
    CH4_DB.TEST.TEST1;
```

You'll notice that we are able to successfully load two different data types into the varchar column, but not at the same time. And once we have two different data types in the varchar column, we can still add additional values.

```
INSERT INTO
    TEST1 (ID, Dept)
VALUES
    (5, 'five');
SELECT
```

```
    *
FROM
    CH4_DB.TEST.TEST1;
```

Multi-row inserts are one way of getting data into Snowflake. Chapter 6 is devoted entirely to data loading and unloading, including in-depth discussion of bulk data loading options and continuous data loading options.

## Query Operators

There are several different types of query operators including arithmetic, comparison, logical, subquery, and set operators.

*Arithmetic operators*, including +, -, *, /, and %, produce a numeric output from one or more inputs. The scale and precision of the output depends on the scale and precision of the input(s). Note that subtraction is the only arithmetic operation allowed on DATE expressions.

*Comparison operators*, typically appearing in a WHERE clause, are used to test the equality of two inputs. Comparison operators include the following:

- Equal (=)
- Not Equal (!=) or (<>)
- Less Than (<)
- Less Than or Equal (<=)
- Greater Than (>)
- Great Than or Equal (>=)

Remember that TIMESTAMP_TZ values are compared based on their times in UTC, which does not account for daylight saving time. This is important because, at the moment of creation, TIMESTAMP_TZ stores the offset of a given time zone, not the actual time zone.

*Logical operators* can only be used in the WHERE clause. The order of precedence of these operators is NOT then AND then OR. *Subquery operators* include [NOT] EXISTS, ANY or ALL, and [NOT] IN.

Queries can be combined when using *set operators* such as INTERSECT, MINUS or EXCEPT, UNION and UNION ALL.

The default set operator order of preference is INTERSECT as the highest precedence, followed by EXCEPT, MINUS and UNION, and finally UNION ALL as the

lowest precedence. Of course, you can always use parenthesis to override the default. Note that the UNION set operation is costly because it needs to sort the records to eliminate duplicate rows.

When using set operators, make sure that each query selects the same number of columns and that the data type of each of the columns is consistent although explicit type cast can be used, if the data types are inconsistent.

## Long Running Queries and Query Performance & Optimization

The Snowflake system will cancel long running queries. The default duration for long running queries is two days but you can always set the STATEMENT_TIMEOUT_IN_SECONDS duration value at an account, session, object, or warehouse level.

During the Snowflake SQL query process, one of the things that happens is the optimization engines find the most efficient execution plan for a specific query. In Chapter 9, we'll learn more about analyzing query performance and optimization techniques as well as how to use Snowflake's query profiler.

## Snowflake Query Limits

SQL statements submitted through Snowflake clients have a query text size limit of one megabyte. Included in that limit are literals, including both string and binary literals. The query text size limit applies to the compressed size of the query. However, because compression ratio for data widely varies, it is recommended to keep the uncompressed query text size below one megabyte.

Additionally, Snowflake limits the number of expressions allowed in a query to 2^14. There are ways to resolve this type of error depending on what are you trying to do with your SQL query statement.

If you're attempting to insert data when you receive the error, try breaking up the statement into smaller queries (Figure 3-6).

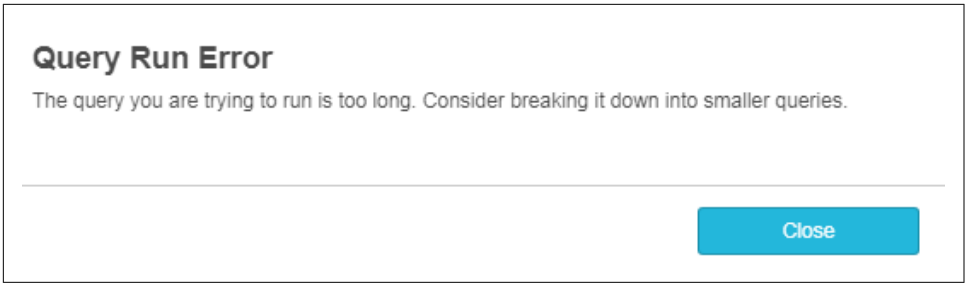



*Figure 3-6. Query Run Error received with the number of expressions exceeds 16,384 values*

However, an even better choice would probably be to use the COPY INTO command instead of the INSERT command.

Another type of query limit error occurs when using a SELECT statement with an IN clause that has greater than 16,384 values .

```
SELECT
    column_1
FROM
    table_1
WHERE
    column_2 IN (1, 2, 3, 4, 5,...);
```

One solution would be to use a JOIN or UNION command after placing those values in a second table.

```
SELECT
    column_1
FROM
    table_1 a
    JOIN table_2 b ON a.column_2 = b.column_2;
```

# Introduction to Data Types Supported by Snowflake

Snowflake supports the basic SQL data types including Geospatial data types and a Boolean logical data type which provides for ternary logic. Snowflake's BOOLEAN data type can have an "unknown" value, or a TRUE or FALSE value. If the Boolean is used in an expression, such as a SELECT statement, then an "unknown" value returns a NULL. If the Boolean is used as a predicate, such as in a WHERE clause, then the "unknown" results will evaluate to FALSE. There are a few data types not supported by Snowflake such as Large Object (LOB), including BLOB and CLOB, as well as ENUM and user-defined data types.

In this section, we'll take a deeper dive into several Snowflake data types such as numeric, string and binary, date and time, semi-structured, and unstructured.

## Numeric Data Types

Snowflake's numeric data types include fixed-point numbers and floating-point numbers, as detailed in Table 4-2. Included in the table is information about each numeric data types' precision and scale. Precision, the total number of digits, impacts storage, whereas scale, the number of digits following the decimal point, does not. However, processing numeric data values with a larger scale could cause slower processing.

*Table 3-2. Snowflake Numeric Data Types*

| **FIXED-POINT NUMBERS Data Type** | | **Comments** |
|---|---|---|
| NUMBER | Optional (38, 0) | Numbers up to 38 digits. Maximum scale is 37 |
| DECIMAL, NUMERIC | Optional (38,0) | Synonymous with NUMBER |
| INT, INTEGER, BIGINT, SMALLINT, TINYINT, BYTEINT | Cannot be specified; always (38,0) | Possible values: -99999999999999999999999999999999999999 to +99999999999999999999999999999999999999 (inclusive) |
| FLOATING-POINT NUMBERS Data Type | | Comments |
| FLOAT, FLOAT4, FLOAT8 | Approximately 15 digits | Values range from approximately 10-308 to 10+308 |
| DOUBLE, DOUBLE PRECISION, REAL | Approximately 15 digits | Synonymous with FLOAT |

It is a known issue that DOUBLE, DOUBLE PRECISION, and REAL columns are stored as DOUBLE but displayed as FLOAT.

Fixed-point numbers are exact numeric values and, as such, are often used for natural numbers and exact decimal values such as monetary amounts. In contrast, floating-point data types are used most often for mathematics and science.

You can see how fixed-point numbers vary based on the data type by trying the following example.

```
CREATE
OR REPLACE DATABASE CH4_DB;
CREATE
OR REPLACE TABLE NUMFIXED (
    NUM NUMBER,
    NUM12 NUMBER(12, 0),
    DECIMAL DECIMAL (10, 2),
    INT INT,
    INTEGER INTEGER
);
```

To see what was created, you can run the "DESC TABLE NUMFIXED;" command and get the results in Figure 4-7.

| | name | type | kind | null? |
|---|---|---|---|---|
| 1 | NUM | NUMBER(38,0) | COLUMN | Y |
| 2 | NUM12 | NUMBER(12,0) | COLUMN | Y |
| 3 | DECIMAL | NUMBER(10,2) | COLUMN | Y |
| 4 | INT | NUMBER(38,0) | COLUMN | Y |
| 5 | INTEGER | NUMBER(38,0) | COLUMN | Y |

*Figure 3-7. Results showing Snowflake Fixed-Point Numbers Data Types*

Now you can compare fixed-point numbers to floating-point numbers by using this next example.

```
DESC TABLE NUMFIXED;
USE DATABASE CH4_DB;
CREATE
OR REPLACE TABLE NUMFLOAT (
    FLOAT FLOAT,
    DOUBLE DOUBLE,
    DP DOUBLE PRECISION,
    REAL REAL
);
```

Once again, use the Describe command to see the results as shown in Figure 3-8.

```
DESC TABLE NUMFLOAT;
```

| | name | type | kind |
|---|---|---|---|
| 1 | FLOAT | FLOAT | COLUMN |
| 2 | DOUBLE | FLOAT | COLUMN |
| 3 | DP | FLOAT | COLUMN |
| 4 | REAL | FLOAT | COLUMN |

*Figure 3-8. Results showing Snowflake Floating-Point Number Data Types*

In traditional computing, float data types are known to be faster for computation. But, is that still an accurate statement about float data types in modern warehouses such as Snowflake? Not necessarily. It is important to consider that integer values can be stored in a compressed format in Snowflake, whereas float data types are not. This

results in less storage space and cost for integers. Querying rows for an integer table type also takes significantly less time.

Because of the inexact nature of floating-point data types, floating-point operations could have small rounding errors and those errors can accumulate, especially when using aggregate functions to process a large number of rows.

Snowflake's numeric data types are supported by numeric constants. Constants, also referred to as literals, represent fixed data values. Numeric digits 0 through 9 can be prefaced by a positive or negative sign. Exponents, indicated by e or E, are also supported in Snowflake numeric constants.

## String & Binary Data Types

Snowflake supports both text and binary string data types, the details of which can be seen in Table 4-3.

*Table 3-3. Snowflake Text and Binary String Data Types*

| TEXT STRINGS Data Type | | Comments |
|---|---|---|
| VARCHAR | Optional parameter (N), max number of characters | Holds Unicode characters; no performance difference between using full-length VARCHAR (16,777,216) or a smaller length |
| CHAR, CHARACTERS | | Synonymous with VARCHAR; length is CHAR(1) if not specified |
| STRING, TEXT | | Synonymous with VARCHAR |
| BINARY | | Has no notion of Unicode characters so length is always measured in bytes; if length not specified then the default is 8 MB, the max length |
| VARBINARY | | Synonymous with BINARY |

You can see how the various text string data types vary by attempting the following example which creates the text string fields and then describes the table.

```
USE DATABASE CH4_DB;
CREATE
OR REPLACE TABLE TEXTSTRING(
    VARCHAR VARCHAR,
    V100 VARCHAR(100),
    CHAR CHAR,
    C100 CHAR(100),
    STRING STRING,
    S100 STRING(100),
    TEXT TEXT,
    T100 TEXT(100)
```

```
);
DESC TABLE TEXTSTRING;
```

If you followed along with the example, you should see the output in Figure 3-9.

| | name | type | kind | null? |
|---|---|---|---|---|
| 1 | VARCHAR | VARCHAR(16777216) | COLUMN | Y |
| 2 | V100 | VARCHAR(100) | COLUMN | Y |
| 3 | CHAR | VARCHAR(1) | COLUMN | Y |
| 4 | C100 | VARCHAR(100) | COLUMN | Y |
| 5 | STRING | VARCHAR(16777216) | COLUMN | Y |
| 6 | S100 | VARCHAR(100) | COLUMN | Y |
| 7 | TEXT | VARCHAR(16777216) | COLUMN | Y |
| 8 | T100 | VARCHAR(100) | COLUMN | Y |

*Figure 3-9. Results of creating a TEXTSTRING table*

Snowflake's string data types are supported by string constants which are always enclosed between delimiters, either single quotes or dollar signs. Using dollar sign symbols as delimiters is especially useful when the string contains many quote characters.

## Date & Time Input / Output Data Types

Snowflake uses the Gregorian Calendar, rather than the Julian Calendar, for all dates and timestamps. The Snowflake date and time data types are summarized in Table 4-4.

*Table 3-4. Snowflake Date and Time Data Types*

| DATE & TIME Data Type | | Comments |
|---|---|---|
| DATE | | Single DATE type; most common date forms are accepted; all accepted timestamps are valid inputs with TIME truncated; the associated time is assumed to be midnight |
| DATETIME | | Alias for TIMESTAMP_NTZ |
| TIME | | Single TIME type in the form HH:MI:SS, internally stored as "wallclock" time; time zones not taken into consideration |
| TIMESTAMP | Default is TIMESTAMP_NTZ | User-specified alias of one of the three TIMESTAMP_variations |
| TIMESTAMP_LTZ | | Internally UTC time with a specified precision; TIMESTAMP with local time zone |
| TIMESTAMP_NTZ | | Internally "wallclock" time; TIMESTAMP without time zone |
| TIMESTAMP_TZ | | Internally UTC time with a time zone offset; TIMESTAMP with time zone |

Snowflake's data and time data types are supported by interval constants as well as date and time constants. Interval constants can be used to add or subtract a specific period of time to or from a date, time, or timestamp. The interval is not a data type and can be used only in date, time, or timestamp arithmetic and will represent seconds if the date or time portion is not specified.

The order of interval increments is important because increments are added or subtracted in the order in which they are listed. This could be important for calculations affected by leap years.

## Semi-structured Data Types

Structured data, known as quantitative data, can be easily stored in a database table as rows and columns whereas semi-structured data, such as XML data, is not schema dependent which makes it more difficult to store in a database. In some situations, however, semi-structured data can be stored in a relational database.

Snowflake supports data types for importing and operating on semi-structured data such as JSON, Avro, ORC, Parquet, and XML data. Snowflake does so through its universal data type VARIANT, a special column type which allows you to store semi-structured data. See Table 4-5 for more information about Snowflake semi-structured data types. Note that it is possible for a VARIANT value to be missing, which is considered to be different from a true null value.

*Table 3-5. Snowflake Semi-Structured Data Types*

| SEMI-STRUCTURED Data Type | | Comments |
|---|---|---|
| VARIANT | Can store Object and Array | Stores values of any other type up to a max of 16 MB uncompressed; internally stored in compressed columnar binary representation |
| OBJECT | | Represents collections of key-value pairs with the key as a non-empty string and the value of VARIANT type |
| ARRAY | | Represents arrays of arbitrary size whose index is a non-negative integer and values have VARIANT type |

When loaded into a VARIANT column, non-native values such as dates and timestamps are stored as strings. As such, storing values this way will likely cause operations to be slower and to consume more than space as compared to storing date and timestamp values in a relational column with the corresponding data type.

## Unstructured Data Types

There are many advantages to using unstructured data, known as qualitative data, to gain insight. Media logs, medical images, audio files of call center recordings, document images and many other types of unstructured data can be used for analytical purposes and for the purpose of sentiment analysis. Storing and governing unstructured data is not easy. Unstructured data is not organized in a predefined manner which means it is not well-suited for relational databases. Typically, unstructured data has been stored in blob storage locations which has several inherent disadvantages, making it difficult and time-consuming to search for files.

To improve searchability of unstructured data, Snowflake recently launched built-in directory tables. Using a tabular file catalog for searches of unstructured data is now as simple as using a SELECT * command on the directory table. Users can also build a table stream on top of a directory table which makes it possible to create pipelines for processing unstructured data. Additionally, Snowflake users can create secure views on directory tables and, thus, are also able to share those secure views with others.

# Snowflake SQL Functions and Session Variables

Snowflake offers users the ability to create user-defined functions and to use external functions, as well as to access many different built-in functions. Session variables also extend Snowflake SQL capabilities.

## Using System Defined (Built-In) Functions

Examples of Snowflake built-in functions include scalar, aggregate, window, table, and system functions.

*Scalar functions* accept a single row or value as an input and then returns one value as a result whereas *aggregate functions* also return a single value but they accept multiple rows or values as inputs.

### Scalar Functions

Some scalar functions operate on a string or binary input value. Examples include CONCAT, LEN, SPLIT, TRIM, UPPER and LOWER case conversion, and REPLACE. Other scalar file functions, such as GET_STAGE_LOCATION, enable you to access files staged in Snowflake cloud storage.

Additionally, there are many things that you can do in Snowflake with date and time data types which include the following examples of scalar date & time functions and data generation functions:

- Construct / Deconstruct (Extract) using month, day, and year components
- Truncate or "Round up" dates to a higher level
- Parse and Format dates using strings
- Add / Subtract to find and use date differences
- Generate system dates or a table of dates

### Aggregate Functions

A Snowflake aggregate function will always return one row even when the input contains no rows. The returned row from an aggregate function where the input contains zero rows could be a zero, an empty string, or some other value. Aggregate functions can be of a general nature, such as MIN, MAX, MEDIAN, MODE, and SUM. Aggregate functions also include linear regression, statistics and probability, frequency estimation, percentile estimation and much more.

Snowflake *window functions* are a special type of aggregate function that can operate on a subset of rows. This subset of related rows is called a "window". Unlike aggregate functions which return a single value for a group of rows, a window function will return an output row for each input row. The output depends not only on the individual row passed to the function but also on the values of the other rows in the window passed to the function.

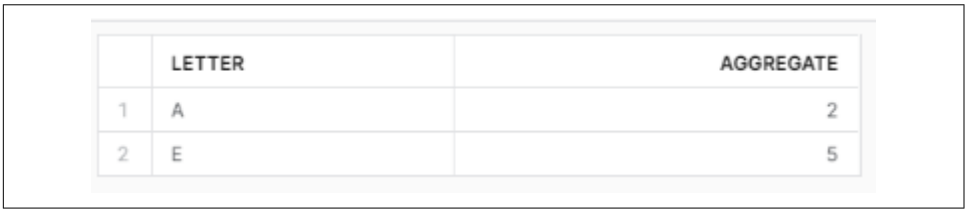
Window functions are commonly used for finding the year-over-year percentage change, a moving average, running or cumulative total and rank rows by groupings or custom criteria.

Let's compare an aggregate function with a window function. In this first example, we'll create an aggregate function by using the vowels in the alphabet and their corresponding locations.

```
SELECT
    LETTER,
    SUM(LOCATION) as AGGREGATE
FROM
    (
        SELECT
            'A' as LETTER,
            1 as LOCATION
        UNION ALL
            (
                SELECT
                    'A' as LETTER,
                    1 as LOCATION
            )
        UNION ALL
            (
                SELECT
```

```
                'E' as LETTER,
                5 as LOCATION
            )
    ) as AGG_TABLE
GROUP BY
    LETTER;
```

The result of this query is shown in Figure 3-10



| | LETTER | AGGREGATE |
|---|---|---|
| 1 | A | 2 |
| 2 | E | 5 |

*Figure 3-10. Result of an aggregate function*

Next, we'll create a window function using the same logic.

```
SELECT
    LETTER,
    SUM(LOCATION) OVER (PARTITION BY LETTER) as WINDOW_FUNCTION
FROM
    (
        SELECT
            'A' as LETTER,
            1 as LOCATION
        UNION ALL
            (
                SELECT
                    'A' as LETTER,
                    1 as LOCATION
            )
        UNION ALL
            (
                SELECT
                    'E' as LETTER,
                    5 as LOCATION
            )
    ) as WINDOW_TABLE;
```

Notice, in Figure , how the Letter 'A' has the same sum value in the window function as in the aggregate function but repeats in the results because the input has two separate 'A' listings.

| | LETTER | WINDOW_FUNCTION |
|---|---|---|
| 1 | A | 2 |
| 2 | A | 2 |
| 3 | E | 5 |

### Table Functions

*Table functions*, often called *tabular functions*, return results in a tabular format with one or more columns and none, one, or many rows. Most Snowflake table functions are 1-to-N functions where each input row generates N output rows but there exist some M-to-N table functions where a group of M input rows produces a group of N output rows. Table functions can be system defined or user defined. Some examples of system defined table functions include VALIDATE, GENERATOR, FLATTEN, RESULT_SCAN, LOGIN_HISTORY, and TASK_HISTORY.

### System Functions

Built-in *system functions* return system-level information, query information, or perform control operations.

One frequently used system information function is the SYSTEM$CLUSTERING_INFORMATION function which returns clustering information, including the average clustering depth, about one or more columns in a table.

System control functions allow you to execute actions in the system. One example of a control function is SYSTEM$CANCEL_ALL_QUERIES and requires the session ID. You can obtain the session ID by logging in as the ACCOUNTADMIN and go to Account > Sessions.

```
SELECT SYSTEM$CANCEL_ALL_QUERIES(<session_id>);
```

If you need to cancel queries for a specific warehouse or user rather than the session, you'll want to use the ALTER command along with ABORT ALL QUERIES instead of a system control function.

## Creating SQL & Javascript User-defined Functions (UDFs) and using Session Variables

SQL functionality can be extended by SQL user Functions (UDF), Javascript UDFs, and session variables. We took a deep dive into both SQL and Javascript User Defined Functions in the previous chapter, *Creating and Managing Snowflake Architecture Objects,* so we'll focus on learning more about session variables in this section.

Snowflake supports SQL variables declared by the user, using the SET command. These session variables exist while a Snowflake session is active. Variables are distinguished in a Snowflake SQL statement by a $ sign prefix and can also contain identifier names when used with objects. You must wrap a variable inside the identifier, such as IDENTIFIER($Variable), to use a variable as an identifier. Alternatively, you can wrap the variable inside of an object in the context of a FROM clause.

To see all the variables defined in the current session, use the SHOW VARIABLES command.

Some examples of session variable functions include:

- SYS_CONTEXT and SET_SYS_CONTEXT
- SESSION_CONTEXT and SET_SESSION_CONTEXT
- GETVARIABLE and SETVARIABLE

All variables created during a session are dropped when a Snowflake session is closed. If you want to destroy a variable during a session, you can use the UNSET command.

## External Functions

An *external function* is a type of user defined function that calls code which is stored and executed outside of Snowflake. Snowflake supports scalar external functions which means the remote service must return exactly one row for each row received. Within Snowflake, the external function is stored as a database object that Snowflake uses to call the remote service.

It is important to note that rather than calling a remote service directly, Snowflake most often calls a proxy service to relay the data to the remote service. Amazon API Gateway and Microsoft Azure API management service are two examples of proxy services that can be used. A remote service can be implemented as an AWS Lambda function, a Microsoft Azure function, or an HTTPS server (e.g. Node.js) running on an EC2 instance.

Any charges by providers of remote services will be billed separately. Snowflake charges normal costs associated with the data transfer and warehouse usage when using external functions.

There are many advantages of using external functions. External functions can be created to be called from other software programs in addition to being called from within Snowflake. Also, the code for the remote services can be written in languages such as Go or C#; languages that cannot be used within other Snowflake UDFs. One of the biggest advantages is that the remote services for Snowflake external functions can be interfaced with commercially available third-party libraries, such as machine-learning scoring libraries.

## Code Cleanup

Code cleanup for this chapter is simple. You can use the following command to drop the database we created earlier.

```
DROP DATABASE CH4_DB;
```

Notice that we don't have to remove all the tables first because dropping the database will automatically drop the associated tables.

## Summary

In this chapter, we created and executed all of our Snowflake queries using the SYSADMIN role. This was done intentionally so that we could focus on learning the basics of Snowflake SQL commands, functions, and statements without adding in the complexity of needing to navigate Snowflake access controls . Now it's time to build on that foundational knowledge of this chapter, along with what we learned in the previous chapter about creating and managing architecture objects.

In the next chapter, we'll take a deep dive into leveraging Snowflake access controls. If you expect to be assigned administrator responsibilities for one of the core admin roles, the next chapter will likely be one of the most important chapters for you in your Snowflake journey of learning. Even if you never expect to perform administrator duties, you'll still need to know how to leverage the full functionality of Snowflake within the permissions you are assigned. Also, even if you are not assigned a Snowflake admin role, it's still likely that you will be given access to perform some functions once reserved only for administrators.

Snowflake has taken great care to design and build access controls that address some of the weaknesses of other platforms. One example of this is that Snowflake has purposely designed an access control system that removes the concept of a "super user", a major risk of many platforms. That said, it is important to recognize that there is still much you can learn about Snowflake's unique access controls even if you have experience with access controls built for other platforms.

## Exercises to Test Your Knowledge

1. What can be used to make a line of text be a comment rather than it being treated as code?
2. Snowflake's string data types are supported by string constants. What delimiters can be used to enclose strings?
3. What are some advantages of using external functions?

4. What is the default duration Snowflake uses to determine when to cancel long running queries? Can you change that duration and, if so, how would you do that?
5. What are the risks of using floating-point number data types?
6. How does a window function differ from an aggregate function?
7. Does Snowflake support unstructured data types?
8. What semi-structured data types does Snowflake support?
9. Do Snowflake's TIMESTAMP data type support local time zones and daylight savings time? Explain.
10. What are derived columns and how can they be used in Snowflake?

Solutions to these exercises are available in Appendix A.

CHAPTER 4

# Leveraging Snowflake Access Controls

### A Note for Early Release Readers

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

This will be the 5th chapter of the final book.

If you have comments about how we might improve the content and/or examples in this book, or if you notice missing material within this chapter, please reach out to the editor at *mcronin@oreilly.com*.

An organization's data repositories are filled with information that is valuable business data and data that is confidential. Securing and protecting this data is therefore essential and often a regulatory or a statutory requirement. Though data security is critical, it must be reasonably balanced against the needs for data access to conduct business. In other words, data access should not be so restrictive as to hobble a business' ability to operate effectively and efficiently for the sake of security. Rather, the necessary data must be made available to just the right users at just the right time without sacrificing security. Developing a good security model involves planning and needs to involve the appropriate stakeholders.

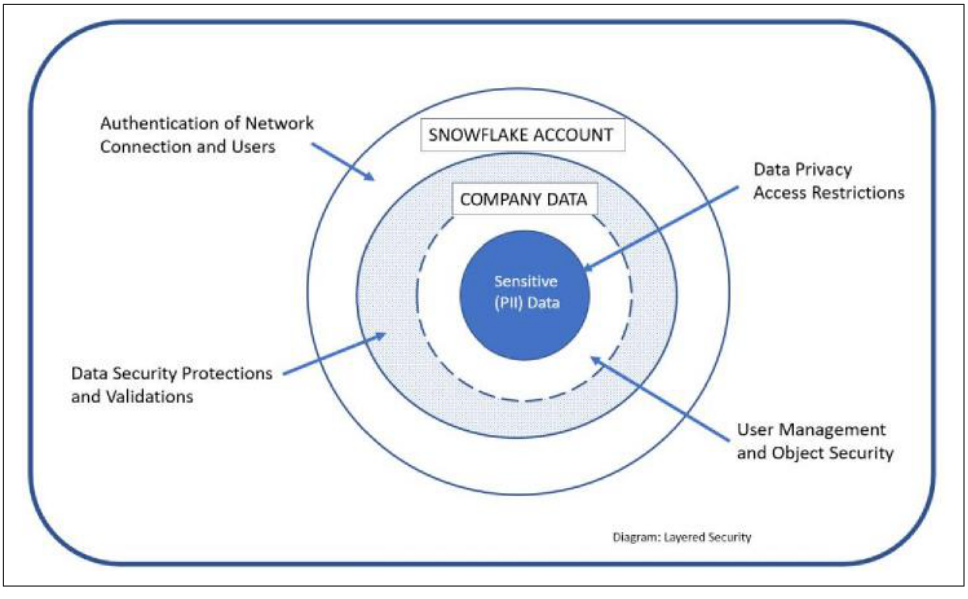



*Figure 4-1. Layered Security*

Creating multiple layers of security that take advantage of Snowflake's built-in security options is among the best practices for managing security. Per Diagram 5-1, the outer security layer as depicted by the outermost concentric circle, relies on network policies, key pair authentication, MFA and Secure Private Networks as options to ensure that only authenticated users gain access to a Snowflake account. Data security protections are provided by Snowflake in the form of having all data within Snowflake encrypted. Both of these outer layers of security are discussed in more detail in Chapter 7. In this chapter, I'll be explaining the next layer, User Management and Object Security. This type of security uses Role Based Access Control (RBAC) and Discretionary Access Control (DAC) to open up the access to certain data for users. Beyond that, data privacy access restrictions are also covered in Chapter 7 and are those things that restrict access such as dynamic data masking, row level security, and use of secure views and secure UDFs to provide limited access to private data.

In this chapter, you will learn how access control is used to secure Snowflake objects by going through a series of examples which build upon each other. Here are the steps you will work through:

1. Learn about Snowflake's access control model.
2. Create securable objects.
3. Create custom roles.
4. Assign role hierarchies.

5. Grant privileges to roles.
6. Assign roles to users.
7. Test and validate the work.
8. Code cleanup.
9. Test your knowledge.
10. Using Access Controls to Secure Snowflake Objects

Snowflake's hybrid access control provides for access at a granular level. A combination of discretionary access control and role-based access control approaches determine who can access what object and perform operations on those objects as well as who can create or alter the access control policies themselves. *Discretionary access control* is a security model where each object has an owner who has control over that object. *Role-based access control* is an approach where access privileges are assigned to roles and roles are then assigned to one or more users.

In the Snowflake hybrid approach, all securable objects are owned by a role rather than a user. Further, each securable object is owned by only one role which is usually the role used to create the object. Note that because a role can be assigned to more than one user, every user granted the same role also has inherent privileges in a shared controlled fashion. Object ownership can be transferred from one role to another. The Snowflake access control key concepts are described by these definitions and Figure 4-2.

- **Securable object**: Entity such as a database or table. Access to a securable object is denied unless specifically granted.
- **Role:** Roles receive privileges to access and perform operations on an object or to create or alter the access control policies themselves. Roles are assigned to users. Roles can also be assigned to other roles, creating a role hierarchy.
- **Privileges**: Inherent, assigned, or inherited access to an object.
- **User:** A person, service account, or program that Snowflake recognizes.

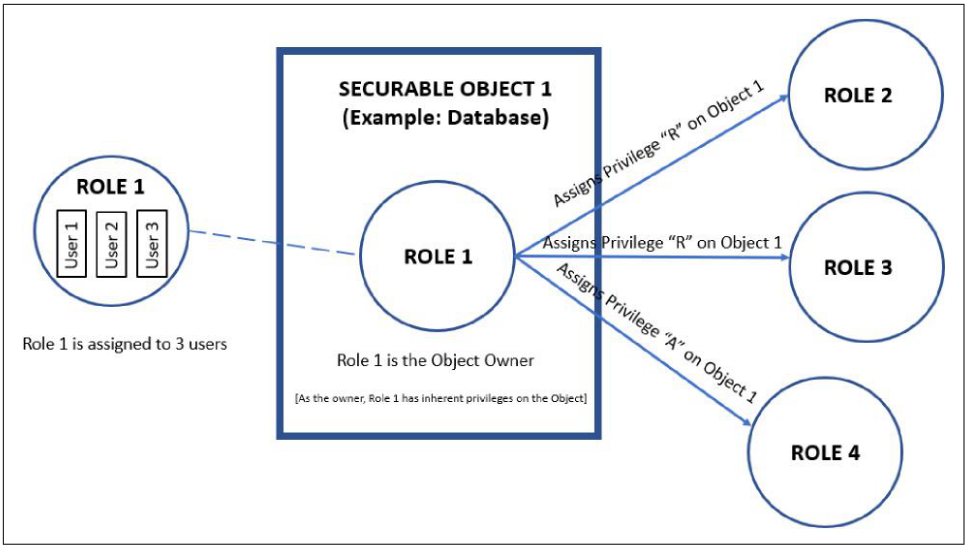



*Figure 4-2. Access Control Key Concepts*

Every securable object resides in a logical container within a hierarchy with customer Account as the top container. Figure 4-3 shows the hierarchy of Snowflake securable objects along with the system-defined role that inherently owns each type of securable object.

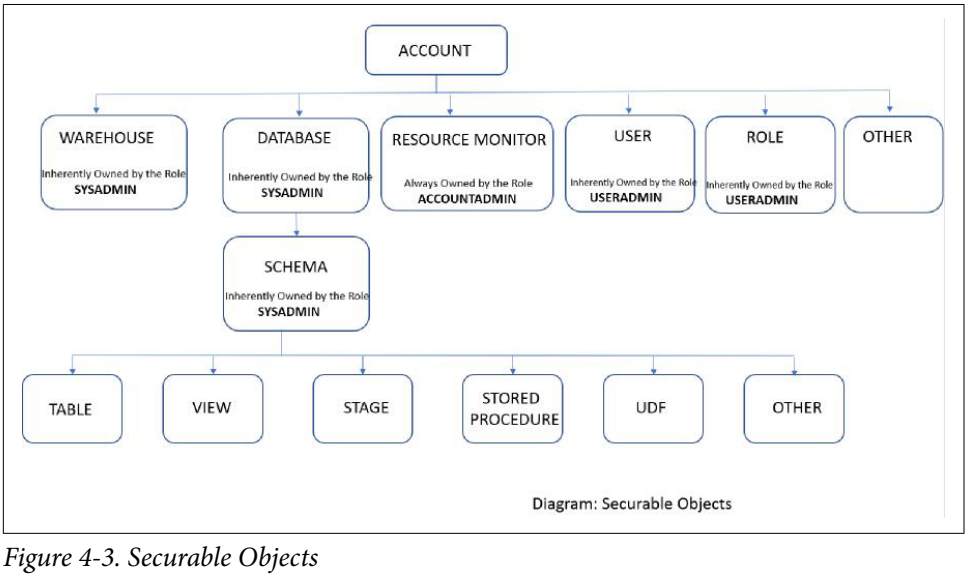



*Figure 4-3. Securable Objects*

Resource Monitors are *always* owned by the ACCOUNTADMIN role. Only the ACCOUNTADMIN can create or drop this object and cannot grant this privilege to any other role. The ACCOUNTADMIN can grant another role the ability to modify a resource monitor already created.

## Creating Securable Objects

To illustrate how Snowflake access controls work, it is necessary to have securable objects in your Snowflake account on which to practice. Let's start by creating a few virtual warehouses which are needed to perform SELECT statements and DML operations. First, the SYSADMIN role is used to create new warehouses. The SHOW command, demonstrated in Figure 4-4, can then be used to confirm that the warehouses were created:

```
USE ROLE SYSADMIN;
CREATE OR REPLACE WAREHOUSE WH_WAREHOUSE1 WITH WAREHOUSE_SIZE='X-SMALL'; CREATE OR
REPLACE WAREHOUSE WH_WAREHOUSE2 WITH WAREHOUSE_SIZE='X-SMALL'; CREATE OR REPLACE
WAREHOUSE WH_WAREHOUSE3 WITH WAREHOUSE_SIZE='X-SMALL'; SHOW WAREHOUSES;
```

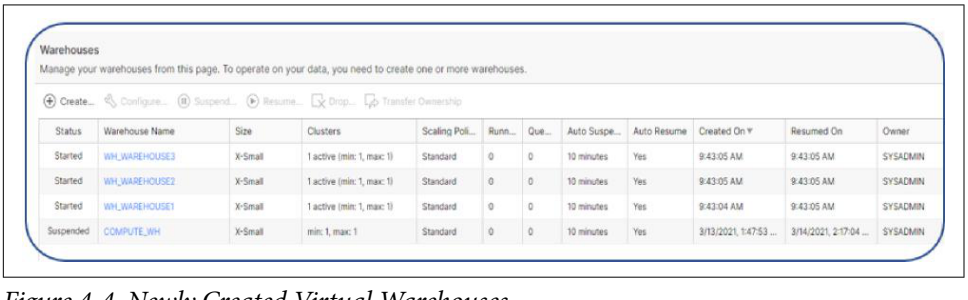



*Figure 4-4. Newly Created Virtual Warehouses*

Next, the SYSADMIN role is used again to create two databases and three schemas.

Before creating these objects, see how the SHOW DATABASES command returns different results depending on the role that is used to issue the command. The difference occurs because the results are meant to return only the databases to which the role has access.

Three databases are included and made available to every role, including the PUBLIC role, at the time when a Snowflake account is created. Therefore, using role SYSADMIN and role PUBLIC to view the list of databases will return the same results, as seen in Figure 4-5 and Figure 4-6:

```
USE ROLE SYSADMIN;
SHOW DATABASES;
```

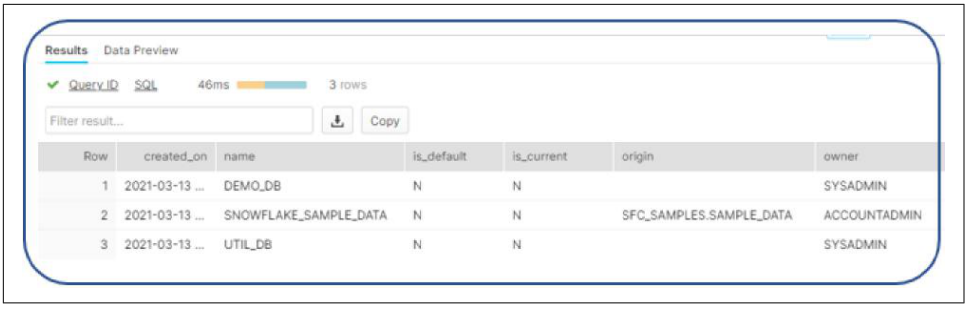



*Figure 4-5. Existing Snowflake Databases Available to the SYSADMIN Role*

```
USE ROLE PUBLIC;
SHOW DATABASES;
```

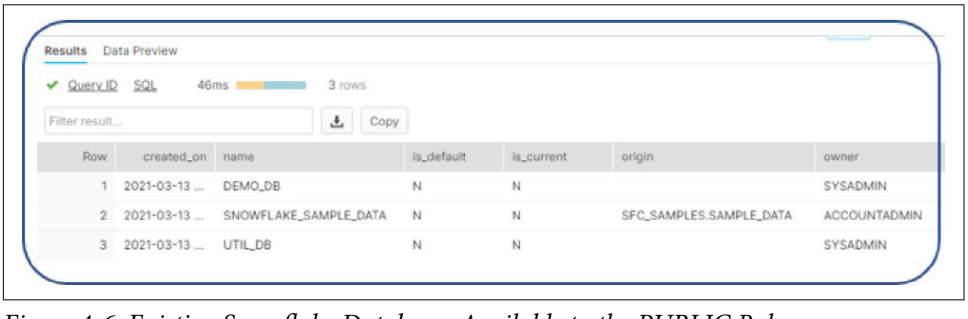



*Figure 4-6. Existing Snowflake Databases Available to the PUBLIC Role*

However, a user assigned the ACCOUNTADMIN role will observe a fourth database listed, shown in Figure 4-7. The additional database is a system-defined and read-only shared database provided by Snowflake.

```
USE ROLE ACCOUNTADMIN;
SHOW DATABASES;
```

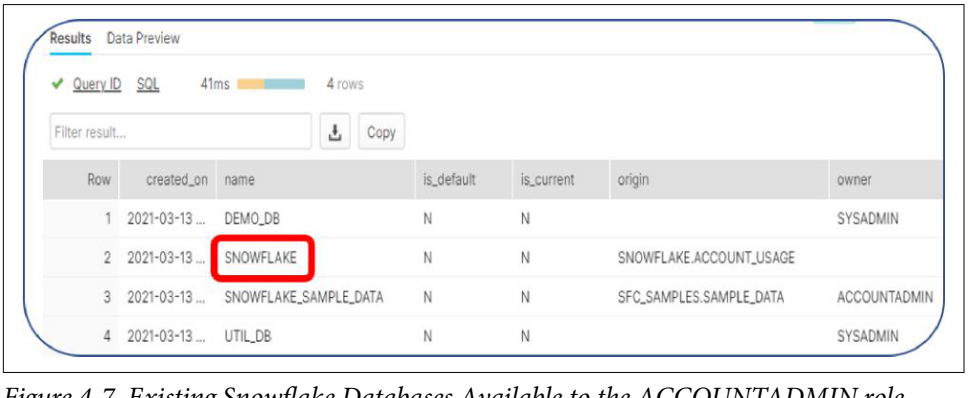



*Figure 4-7. Existing Snowflake Databases Available to the ACCOUNTADMIN role*

Let's use the SYSADMIN role to create the databases and schemas.

The order in which the SQL commands are written to create databases and schemas is important. Create schemas immediately after creating the database or use the fully qualified object names for creating the schema.

For DB1, we'll create the schema at the end using the fully qualified object name and for DB2 we'll create the schemas right after creating the database. The results are shown in Figure 5-8.

```
USE ROLE SYSADMIN;
CREATE OR REPLACE DATABASE DB1;
CREATE OR REPLACE DATABASE DB2;
CREATE OR REPLACE SCHEMA DB2_SCHEMA1;
CREATE OR REPLACE SCHEMA DB2_SCHEMA2;
CREATE OR REPLACE SCHEMA DB1.DB1_SCHEMA1;
SHOW DATABASES;
```

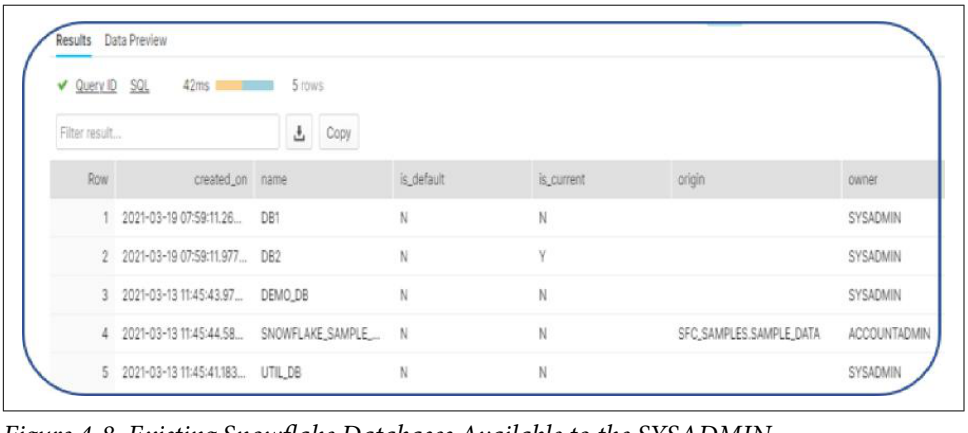


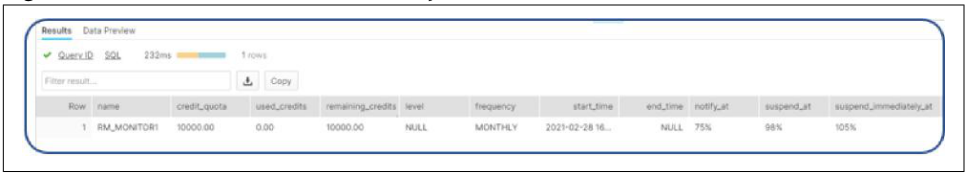

*Figure 4-8. Existing Snowflake Databases Available to the SYSADMIN*

Resource Monitors will be described in more detail in Chapter 8. Only an Account Administrator can create a Resource Monitor. The results of creating the Resource Monitor can be seen in Figure 4-9.

```
USE ROLE ACCOUNTADMIN;
CREATE OR REPLACE RESOURCE MONITOR RM_MONITOR1 WITH CREDIT_QUOTA=10000
TRIGGERS ON 75 PERCENT DO NOTIFY
ON 98 PERCENT DO SUSPEND
```

```
ON 105 PERCENT DO SUSPEND_IMMEDIATE;
SHOW RESOURCE MONITORS;
```

*Figure 4-9. Resource Monitor Created by the SYSADMIN Role*




Later in this chapter, we'll explore Snowflake User Management in detail. For now, let's create a few users with minimum information:

```
USE ROLE USERADMIN;
CREATE OR REPLACE USER USER1
LOGIN_NAME=ARNOLD; CREATE OR REPLACE USER USER2
LOGIN_NAME=BEATRICE; CREATE OR REPLACE USER USER3
LOGIN_NAME=COLLIN;
CREATE OR REPLACE USER USER4 LOGIN_NAME=DIEDRE;
```

Our first inclination to view a listing of all users would be to use the same role used to create the users, the USERADMIN role. An error is received, shown in Figure 4-10, when we make this attempt because the USERADMIN role does not inherently have sufficient privileges to view a list of users:

```
USE ROLE USERADMIN;
SHOW USERS;
```

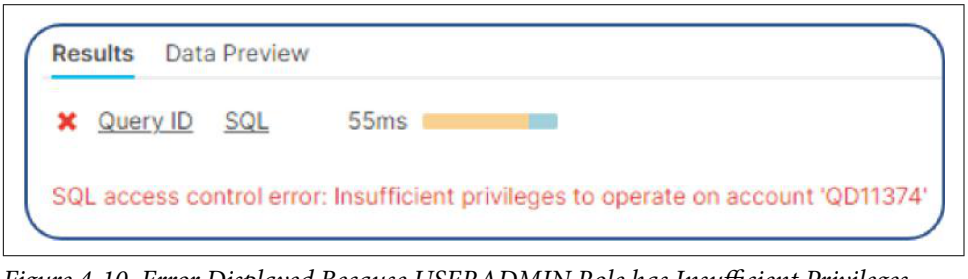



*Figure 4-10. Error Displayed Because USERADMIN Role has Insufficient Privileges*

However, the listing of all users can be viewed by using the role in the hierarchy just above the USERADMIN role, as shown in Figure 4-11.

```
USE ROLE SECURITYADMIN;
SHOW USERS;
```

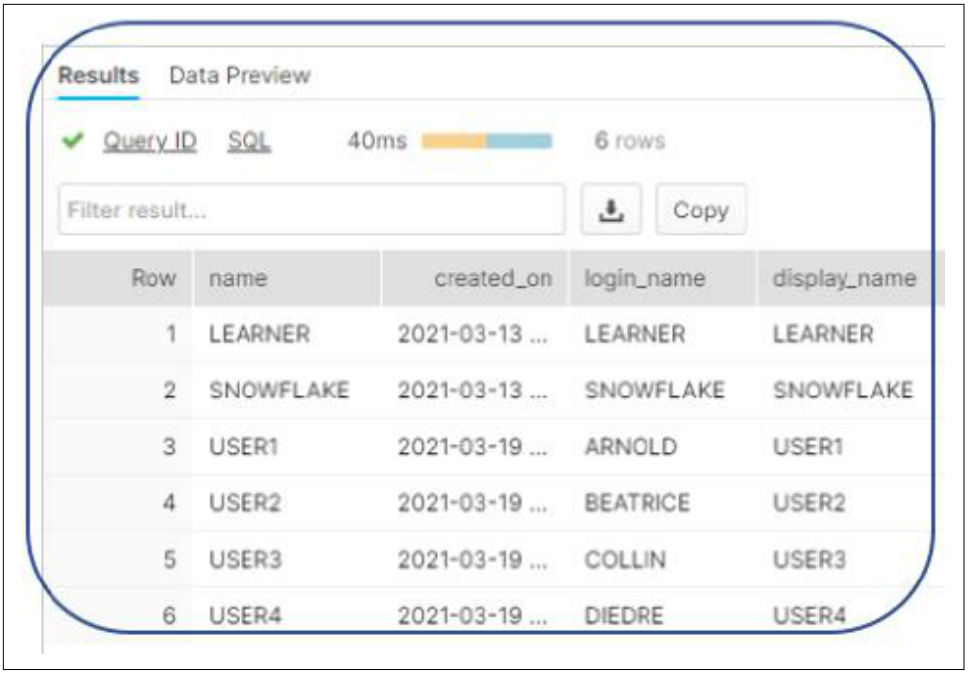



*Figure 4-11. Listing of Snowflake Users*

## Snowflake System-Defined Roles

A Snowflake role, which is assigned to a user, is an entity to which privileges can be assigned. Assigned privileges do not come with the GRANT option, the ability to grant the assigned privilege to another role, unless specifically assigned. Roles can also be granted to other roles which creates a *role hierarchy*. With this role hierarchy structure, privileges are also inherited by all roles above a particular role in the hierarchy. A user can have multiple roles and can switch between roles, though only one role can be active in a current Snowflake session. As illustrated in the diagram, there are a small number of system-defined roles in a Snowflake account.

As shown in Figure 4-12, the Account Administrator (ACCOUNTADMIN) is at the top level of system-defined roles and can view and operate on all objects in the account with one exception. The Account Administrator will have no access to an object when the object is created by a custom role without an assigned system-defined role. The ACCOUNTADMIN role can stop any running SQL statements and can view and manage Snowflake billing. Privileges for Resource Monitors are unique to the ACCOUNTADMIN role. None of the inherent privileges that come with the Resource Monitor privileges come with the GRANT option but the ACCOUNTADMIN can assign the ALTER Resource Monitor privilege to another role. It is a best

practice to limit the ACCOUNTADMIN role to the minimum number of users required to maintain control of the Snowflake account, but to no less than two users.

Snowflake has no concept of a "Super User" or a "Super Role". All access to securable objects, even by the Account Administrator, requires access privileges granted explicitly when the ACCOUNTADMIN creates objects itself, or implicitly by being in a higher hierarchy role. As such, if a custom role is created that without assignment to another role in a hierarchy that ultimately leads to the ACCOUNTADMIN role, then any securable objects created by that role would be inaccessible by the Account Administrator.

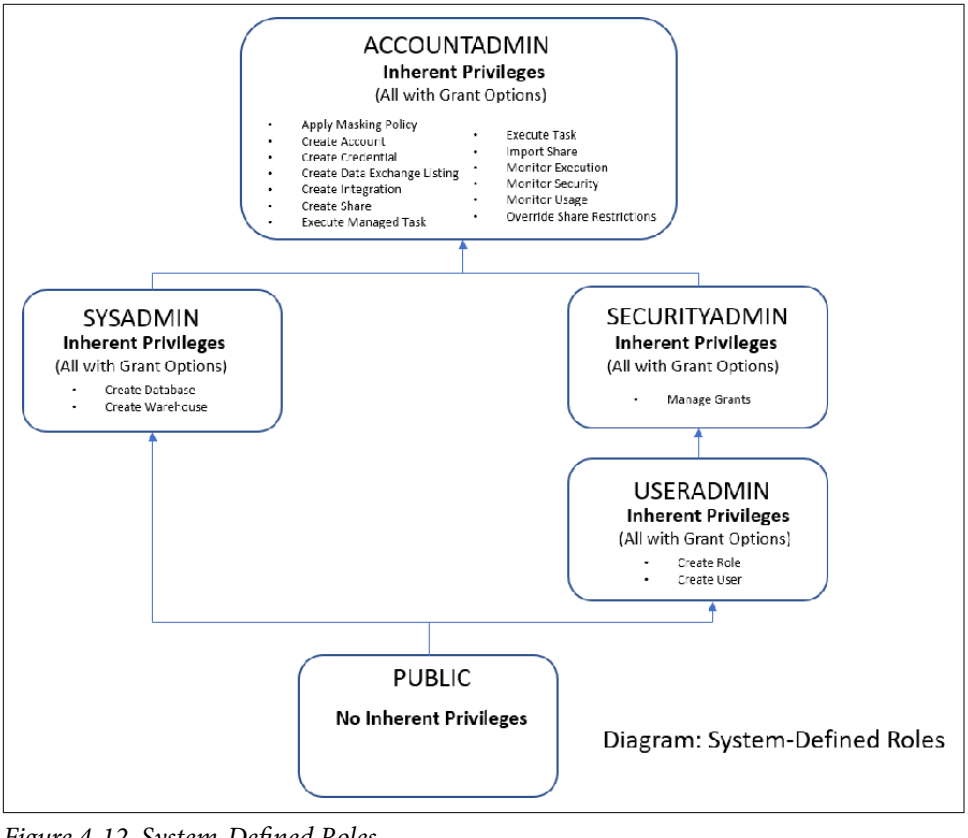



*Figure 4-12. System-Defined Roles*

In addition to the Account Administrator, other system-defined roles can manage security for objects in the system by using the inherent privileges assigned to them. Those privileges can be granted to other roles in Snowflake, including custom roles, to assign the responsibility for managing security in the system. An example of when

the ACCOUNTADMIN assigns the "Apply Masking Policy" privilege to a custom role will be covered later.

The Security Administrator (SECURITYADMIN) is inherently given the MANAGE GRANTS privilege as well as inheriting all the privileges of the USERADMIN role. The User Administrator (USERADMIN) is responsible for creating and managing users and roles.

The System Administrator (SYSADMIN) role is a system-defined role with privileges to create warehouses, databases, and other objects in the Snowflake account. The most common roles created by the USERADMIN are assigned to the SYSADMIN role, thus enabling the System or Account Administrator to manage any of the objects created by custom roles.

The PUBLIC role is automatically granted to every role and every user in the Snowflake account. Just like any other role, the PUBLIC role can own securable objects.

It is important to remember that any privileges or object access provided to the PUBLIC role is then available to all roles and all users in the account because of the system role hierarchy.

## Creating Custom Roles

Creating and managing custom roles are one of the most important functions in Snowflake. Before creating custom roles, planning should be undertaken to design a custom role architecture that will secure and protect sensitive data but not be unnecessarily restrictive. Involved in the planning discussion should be the data stewards, the governance committee, the staff who understand the business needs, and the IT professionals. There is an example in this chapter of an approach for creating custom roles. The approach I've taken is to divide the custom roles into *functional-level custom roles*, which include Business and IT roles, and *system-level custom roles,* which include service account roles and object access roles.

Let's look at the roles that exist in the Snowflake account we created in preparation for creating new custom roles. The command to show roles will return a list of the role names as well as some additional information. In Figure 4-13, for the USERADMIN role, we see the "is_current" status is Y and the "is_inherited" is Y for the PUBLIC role. This which means that the USERADMIN role is the role currently in use and above the public role in the hierarchy, thus, it will inherit any privileges assigned to the PUBLIC role:

```
USE ROLE USERADMIN;
SHOW ROLES;
```

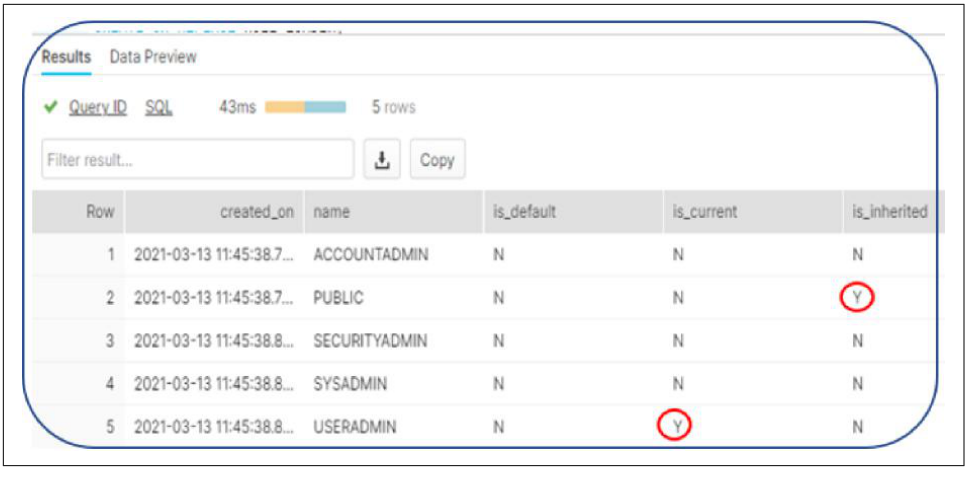



*Figure 4-13. Showing USERADMIN Role as the Current User*

As shown in Figure 4-14, the Security Administrator role inherits privileges from the USERADMIN and the PUBLIC role:

```
USE ROLE SECURITYADMIN;
SHOW ROLES;
```

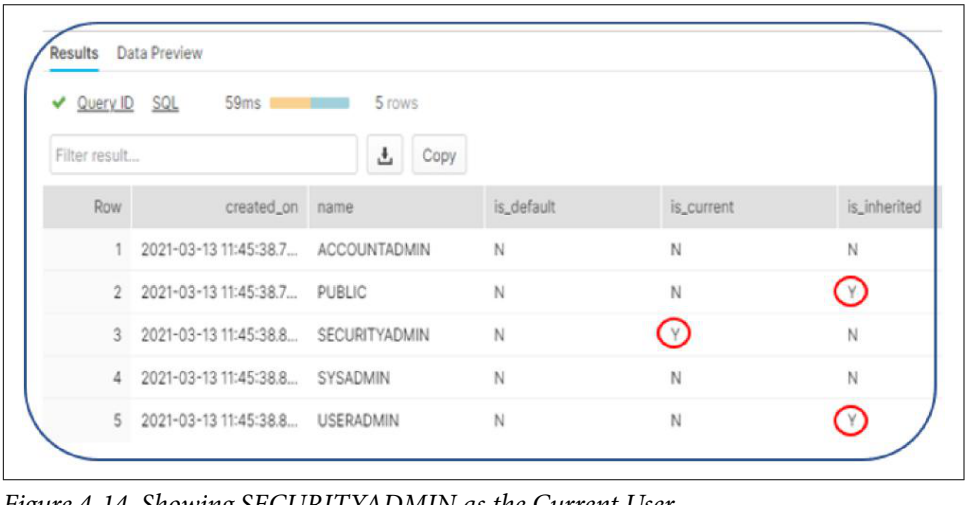



*Figure 4-14. Showing SECURITYADMIN as the Current User*

## Functional-Level Business & IT Roles

You'll notice that in Figure 4-15, I chose to use suffixes to differentiate between levels, such as Sr for Senior Analyst and Jr for Junior Analyst. I chose to use prefixes for

roles where different environments might be needed, such as SBX for Sandbox, DEV for Development, and PRD for Production Environment.

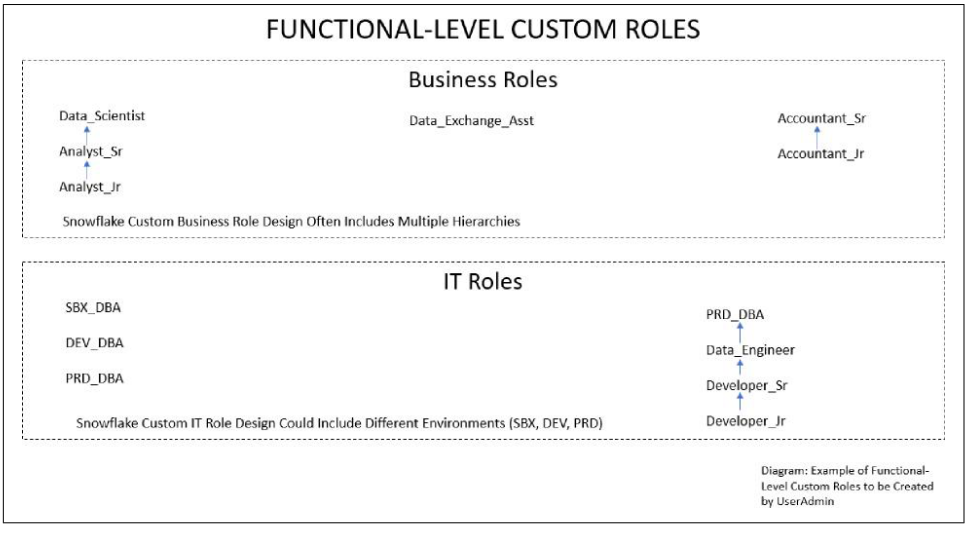



*Figure 4-15. Functional-Level Custom Roles*

We use the USERADMIN role to create our 10 functional custom roles:

```
USE ROLE USERADMIN;
CREATE OR REPLACE ROLE DATA_SCIENTIST;
CREATE OR REPLACE ROLE ANALYST_SR;
CREATE OR REPLACE ROLE ANALYST_JR;
CREATE OR REPLACE ROLE DATA_EXCHANGE_ASST;
CREATE OR REPLACE ROLE ACCOUNTANT_SR;
CREATE OR REPLACE ROLE ACCOUNTANT_JR;
CREATE OR REPLACE ROLE PRD_DBA;
CREATE OR REPLACE ROLE DATA_ENGINEER;
CREATE OR REPLACE ROLE DEVELOPER_SR;
CREATE OR REPLACE ROLE DEVELOPER_JR;
SHOW ROLES;
```

By using the SHOW command, you'll find that none of the custom roles have been granted to other roles. It is otherwise important to have all custom roles assigned to another role in the hierarchy with the top custom role being assigned to either the SYSADMIN role or the ACCOUNTADMIN role, unless there is a business need to isolate a custom role. Later in this chapter, we'll complete the hierarchy of custom roles by assigning the custom roles to a system-defined role.

## System-Level Service Account and Object Access Roles

For System-Level custom roles, as shown in Figure 4-16, I've created two different types of roles. The service account roles are typically those roles used for data loading

or connecting to visualization tools. The object access roles are roles for which data access privileges, such as the ability to view the data in a particular schema or to insert data into a table, will be granted. These object access roles then will be assigned to other roles higher up in the hierarchy.

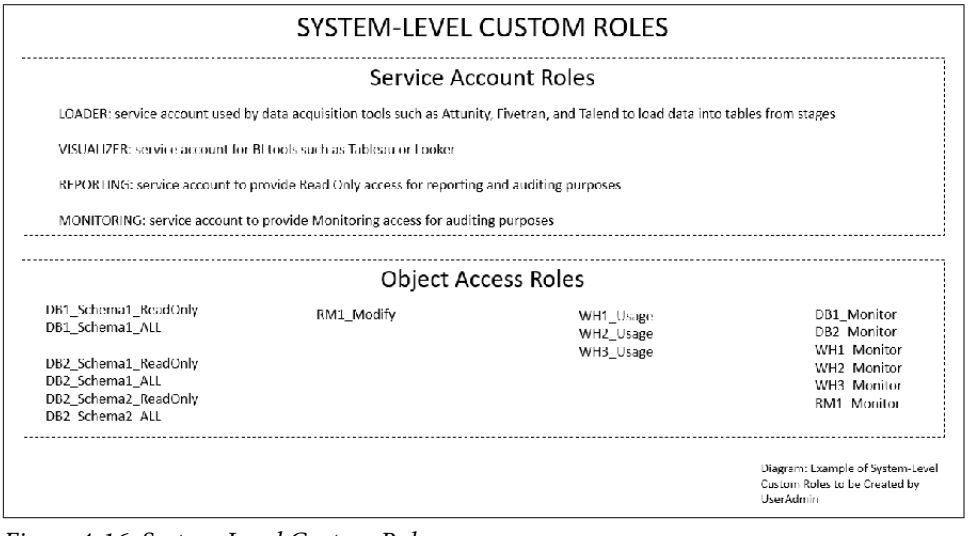



*Figure 4-16. System-Level Custom Roles*

First, let's use the USERADMIN role to create system service account roles:

```
USE ROLE USERADMIN;
CREATE OR REPLACE ROLE LOADER;
CREATE OR REPLACE ROLE VISUALIZER;
CREATE OR REPLACE ROLE REPORTING;
CREATE OR REPLACE ROLE MONITORING;
```

Next, create the system object access roles:

```
USE ROLE USERADMIN;
CREATE OR REPLACE ROLE DB1_SCHEMA1_READONLY;
CREATE OR REPLACE ROLE DB1_SCHEMA1_ALL;
CREATE OR REPLACE ROLE DB2_SCHEMA1_READONLY;
CREATE OR REPLACE ROLE DB2_SCHEMA1_ALL;
CREATE OR REPLACE ROLE DB2_SCHEMA2_READONLY;
CREATE OR REPLACE ROLE DB2_SCHEMA2_ALL;
CREATE OR REPLACE ROLE RM1_MODIFY;
CREATE OR REPLACE ROLE WH1_USAGE;
CREATE OR REPLACE ROLE WH2_USAGE;
CREATE OR REPLACE ROLE WH3_USAGE;
CREATE OR REPLACE ROLE DB1_MONITOR; CREATE OR REPLACE ROLE DB2_MONITOR; CREATE OR
REPLACE ROLE WH1_MONITOR; CREATE OR REPLACE ROLE WH2_MONITOR; CREATE OR REPLACE
ROLE WH3_MONITOR; CREATE OR REPLACE ROLE RM1_MONITOR;
```

# Role Hierarchy Assignments: Assign Roles to Other Roles

As I covered earlier, we want to assign the object access roles to other roles in the role hierarchy. As part of Figure 4-17, you'll see that it is necessary to also assign a warehouse to any role that we expect would need the ability to run queries.

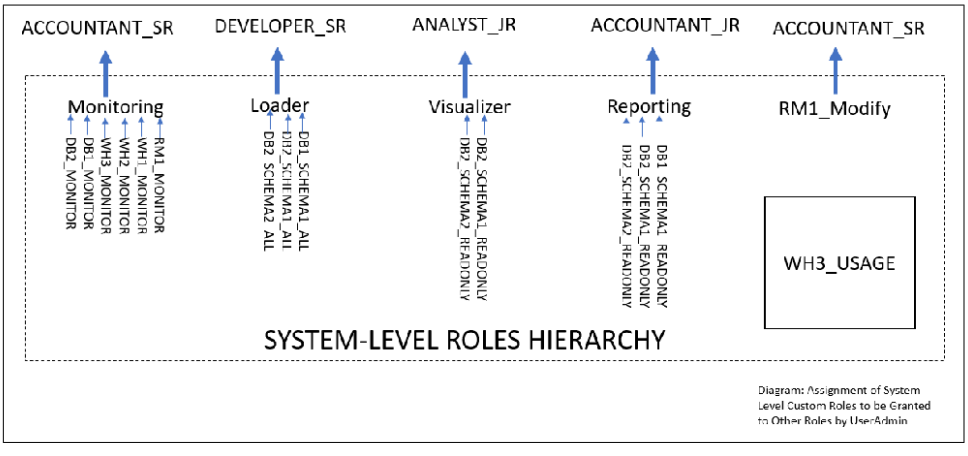



*Figure 4-17. System-Level Roles Hierarchy*

We'll now complete the system-Level role hierarchy assignments:

```
USE ROLE USERADMIN;
GRANT ROLE RM1_MONITOR TO ROLE MONITORING; GRANT ROLE WH1_MONITOR TO ROLE MONITOR-
ING; GRANT ROLE WH2_MONITOR TO ROLE MONITORING; GRANT ROLE WH3_MONITOR TO ROLE MONI-
TORING; GRANT ROLE DB1_MONITOR TO ROLE MONITORING; GRANT ROLE DB2_MONITOR TO ROLE
MONITORING; GRANT ROLE WH3_USAGE TO ROLE MONITORING;
GRANT ROLE DB1_SCHEMA1_ALL TO ROLE LOADER; GRANT ROLE DB2_SCHEMA1_ALL TO ROLE
LOADER; GRANT ROLE DB2_SCHEMA2_ALL TO ROLE LOADER; GRANT ROLE WH3_USAGE TO ROLE
LOADER;
GRANT ROLE DB2_SCHEMA1_READONLY TO ROLE VISUALIZER; GRANT ROLE DB2_SCHEMA2_READONLY
TO ROLE VISUALIZER; GRANT ROLE WH3_USAGE TO ROLE VISUALIZER;
GRANT ROLE DB1_SCHEMA1_READONLY TO ROLE REPORTING; GRANT ROLE DB2_SCHEMA1_READONLY
TO ROLE REPORTING; GRANT ROLE DB2_SCHEMA2_READONLY TO ROLE REPORTING; GRANT ROLE
WH3_USAGE TO ROLE REPORTING;
GRANT ROLE MONITORING TO ROLE ACCOUNTANT_SR;
GRANT ROLE LOADER TO ROLE DEVELOPER_SR;
GRANT ROLE VISUALIZER TO ROLE ANALYST_JR;
GRANT ROLE REPORTING TO ROLE ACCOUNTANT_JR;
GRANT ROLE RM1_MODIFY TO ROLE ACCOUNTANT_SR;
```

Completing the functional-level role hierarchy assignments means that we'll also want to assign the top-level custom role to either the SYSADMIN or the ACCOUNTADMIN role as a final step in the hierarchy assignment process. As before, we'll also want to assign a warehouse to any role that we expect would need the ability to run queries. This is demonstrated in Figure 5-18.

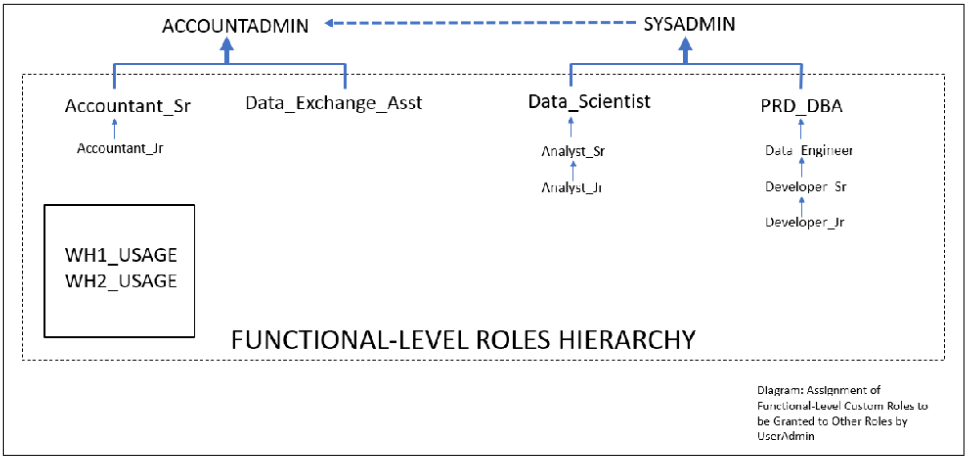



*Figure 4-18. Functional-Level Roles Hierarchy*

The USERADMIN role is used to complete the functional role hierarchy assignments:

```
USE ROLE USERADMIN;
GRANT ROLE ACCOUNTANT_JR TO ROLE ACCOUNTANT_SR;
GRANT ROLE ANALYST_JR TO ROLE ANALYST_SR;
GRANT ROLE ANALYST_SR TO ROLE DATA_SCIENTIST;
GRANT ROLE DEVELOPER_JR TO ROLE DEVELOPER_SR;
GRANT ROLE DEVELOPER_SR TO ROLE DATA_ENGINEER;
GRANT ROLE DATA_ENGINEER TO ROLE PRD_DBA;
GRANT ROLE ACCOUNTANT_SR TO ROLE ACCOUNTADMIN;
GRANT ROLE DATA_EXCHANGE_ASST TO ROLE ACCOUNTADMIN;
GRANT ROLE DATA_SCIENTIST TO ROLE SYSADMIN;
GRANT ROLE PRD_DBA TO ROLE SYSADMIN;
```

Next, be sure to grant usage of Warehouse1 directly to IT roles and usage of Warehouse2 to business

roles:

```
GRANT ROLE WH1_USAGE TO ROLE DEVELOPER_JR;
GRANT ROLE WH1_USAGE TO ROLE DEVELOPER_SR;
GRANT ROLE WH1_USAGE TO ROLE DATA_ENGINEER;
GRANT ROLE WH1_USAGE TO ROLE PRD_DBA;
GRANT ROLE WH2_USAGE TO ROLE ACCOUNTANT_JR;
GRANT ROLE WH2_USAGE TO ROLE ACCOUNTANT_SR;
GRANT ROLE WH2_USAGE TO ROLE DATA_EXCHANGE_ASST;
GRANT ROLE WH2_USAGE TO ROLE ANALYST_JR;
GRANT ROLE WH2_USAGE TO ROLE ANALYST_SR;
GRANT ROLE WH2_USAGE TO ROLE DATA_SCIENTIST;
```

# Granting Privileges to Roles

Snowflake privileges are a defined level of access to a securable object. The granularity of access can be granted by using different distinct privileges and privileges can also be revoked if necessary. Each securable object has a specific set of privileges which can be granted on it and for existing objects, these privileges must be granted on the individual object. To make grant management more flexible and simpler, future grants can be assigned on objects created in a schema. I've elected here to assign the following privileges to the roles shown in Figure 5-19. These particular privileges are privileges that only the Account Administrator can assign.

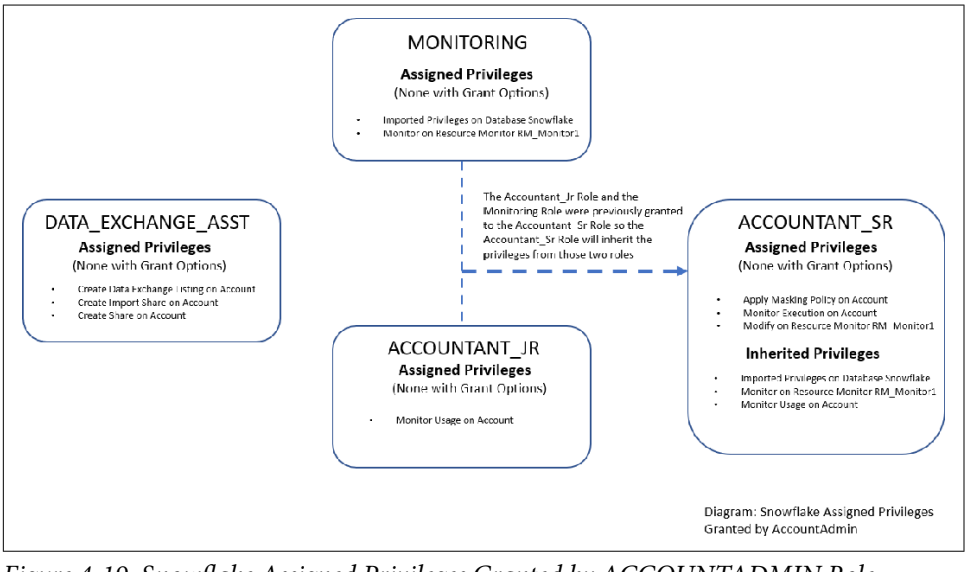



*Figure 4-19. Snowflake Assigned Privileges Granted by ACCOUNTADMIN Role*

The ACCOUNTADMIN role is required to grant direct global privileges to the functional Roles. We also will need to use the ACCOUNTADMIN role to grant privileges to custom roles that only the Account Administrator can grant:

```
USE ROLE ACCOUNTADMIN;
GRANT CREATE DATA EXCHANGE LISTING ON ACCOUNT TO ROLE DATA_EXCHANGE_ASST;
GRANT IMPORT SHARE ON ACCOUNT TO ROLE DATA_EXCHANGE_ASST;
GRANT CREATE SHARE ON ACCOUNT TO ROLE DATA_EXCHANGE_ASST;
GRANT IMPORTED PRIVILEGES ON DATABASE SNOWFLAKE TO ROLE MONITORING;
GRANT MONITOR ON RESOURCE MONITOR RM_MONITOR1 TO ROLE MONITORING;
GRANT MONITOR USAGE ON ACCOUNT TO ROLE ACCOUNTANT_JR;
GRANT APPLY MASKING POLICY ON ACCOUNT TO ROLE ACCOUNTANT_SR;
GRANT MONITOR EXECUTION ON ACCOUNT TO ROLE ACCOUNTANT_SR;
GRANT MODIFY ON RESOURCE MONITOR RM_MONITOR1 TO ROLE ACCOUNTANT_SR;
```

A number of different custom roles need privileges to interact with data in objects and need the ability to use a warehouse to make that interaction. For the ability to view data in a table, a role needs privileges to use the database and schema in which the table resides as well as the ability to use the SELECT command on the table. The privileges will be assigned for any existing objects in the schema when these privileges are granted. We'll also want to consider assigning FUTURE GRANT privileges so that the role can access tables created in the future. Future grants can only be assigned by the ACCOUNTADMIN, therefore we'll have to assign future grant access in a later step. Notice in Figure 4-20 that the object monitoring privilege is set at the database level, thus, the role will be able to monitor both databases we created and all objects below the databases in the hierarchy.

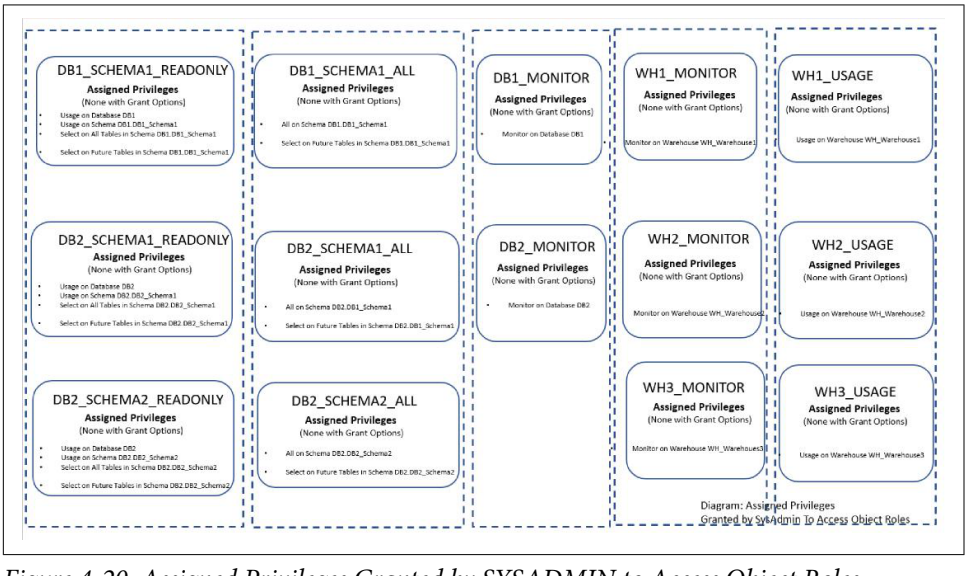



*Figure 4-20. Assigned Privileges Granted by SYSADMIN to Access Object Roles*

Notice that the System Administrator role, not the User Administrator role, is required to grant privileges. Use the SECURITYADMIN Role to Grant Direct assigned privileges to system-level object access roles:

```
USE ROLE SYSADMIN;
GRANT USAGE ON DATABASE DB1 TO ROLE DB1_SCHEMA1_READONLY;
GRANT USAGE ON DATABASE DB2 TO ROLE DB2_SCHEMA1_READONLY;
GRANT USAGE ON DATABASE DB2 TO ROLE DB2_SCHEMA2_READONLY;
GRANT USAGE ON SCHEMA DB1.DB1_SCHEMA1 TO ROLE DB1_SCHEMA1_READONLY; GRANT USAGE ON
SCHEMA DB2.DB2_SCHEMA1 TO ROLE DB2_SCHEMA1_READONLY; GRANT USAGE ON SCHEMA
DB2.DB2_SCHEMA2 TO ROLE DB2_SCHEMA2_READONLY;
GRANT SELECT ON ALL TABLES IN SCHEMA DB1.DB1_SCHEMA1 TO ROLE
DB1_SCHEMA1_READONLY;
GRANT SELECT ON ALL TABLES IN SCHEMA DB2.DB2_SCHEMA1 TO ROLE
DB2_SCHEMA1_READONLY;
```

```
GRANT SELECT ON ALL TABLES IN SCHEMA DB2.DB2_SCHEMA2 TO ROLE
DB1_SCHEMA1_READONLY;

GRANT ALL ON SCHEMA DB1.DB1_SCHEMA1 TO ROLE DB1_SCHEMA1_ALL; GRANT ALL ON SCHEMA
DB2.DB2_SCHEMA1 TO ROLE DB2_SCHEMA1_ALL; GRANT ALL ON SCHEMA DB2.DB2_SCHEMA2 TO
ROLE DB2_SCHEMA2_ALL;
GRANT MONITOR ON DATABASE DB1 TO ROLE DB1_MONITOR;
GRANT MONITOR ON DATABASE DB2 TO ROLE DB2_MONITOR;
GRANT MONITOR ON WAREHOUSE WH_WAREHOUSE1 TO ROLE WH1_MONITOR; GRANT MONITOR ON WARE-
HOUSE WH_WAREHOUSE2 TO ROLE WH2_MONITOR; GRANT MONITOR ON WAREHOUSE WH_WAREHOUSE3
TO ROLE WH3_MONITOR;
GRANT USAGE ON WAREHOUSE WH_WAREHOUSE1 TO WH1_USAGE;
GRANT USAGE ON WAREHOUSE WH_WAREHOUSE2 TO WH2_USAGE;
GRANT USAGE ON WAREHOUSE WH_WAREHOUSE3 TO WH3_USAGE;
```

Use the ACCOUNTADMIN Role to Grant FUTURE Direct Assigned Privileges:

```
USE ROLE ACCOUNTADMIN;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB1.DB1_SCHEMA1 TO ROLE
DB1_SCHEMA1_READONLY;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB2.DB2_SCHEMA1 TO ROLE
DB2_SCHEMA1_READONLY;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB2.DB2_SCHEMA2 TO ROLE
DB2_SCHEMA2_READONLY;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB1.DB1_SCHEMA1 TO ROLE DB1_SCHEMA1_ALL;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB2.DB2_SCHEMA1 TO ROLE DB2_SCHEMA1_ALL;
GRANT SELECT ON FUTURE TABLES IN SCHEMA DB2.DB2_SCHEMA2 TO ROLE DB2_SCHEMA2_ALL;
```

# Assigning Roles to Users

We created four users earlier in the chapter. Now, let's assign roles to each of those four users. It is possible to assign more than one role to each user but only one role can be used at any given time (i.e., assigned roles cannot be 'layered' or combined). Remember, that for any role that is assigned for which there are roles below in the hierarchy, the user has already inherited that role. For example, the Data Scientist role inherits the Analyst Sr and Analyst Jr role and will see those roles in their account. Accordingly, it would be redundant to assign either of those two roles to a user who is assigned the Data Scientist role.

```
USE ROLE USERADMIN;
GRANT ROLE DATA_EXCHANGE_ASST TO USER USER1;
GRANT ROLE DATA_SCIENTIST TO USER USER2;
GRANT ROLE ACCOUNTANT_SR TO USER USER3;
GRANT ROLE PRD_DBA TO USER USER4;
```

# Testing and Validating Our Work

Now is when we get to test and validate the work we completed to establish our access control security.

When running any of the queries using any of the custom roles, you'll need to have a running warehouse to complete the queries. If, at any time, you receive an error message that there is no running warehouse, then you can always use the SHOW command to find a list of available warehouses for that role and the USE command to get the warehouse running.

For example, the role PRD_DBA has available both Warehouse1, which was assigned to the role, and Warehouse3, which was inherited. This is evidenced in Figure 4-21.

```
USE ROLE PRD_DBA;
SHOW WAREHOUSES;
```


*Figure 4-21. Current Snowflake Warehouses Available to Role PRD_DBA*

So, to run any query, the PRD_DBA role use Warehouse3:

```
USE WAREHOUSE WH_WAREHOUSE3;
```

or, alternatively, can use Warehouse1:

```
USE WAREHOUSE WH_WAREHOUSE1;
```

Access to the SNOWFLAKE database should be granted to a minimum number of people. The ACCOUNTADMIN role has access to the Snowflake table and earlier we used the ACCOUNTADMIN role to grant access to the Senior Accountant. Therefore, we would expect an error returned if the Junior Accountant attempted to access the table. This is confirmed in Figure 4-22.

```
USE ROLE ACCOUNTANT_JR;
SELECT * FROM SNOWFLAKE.ACCOUNT_USAGE.QUERY_HISTORY WHERE QUERY_TYPE =
'GRANT';
```

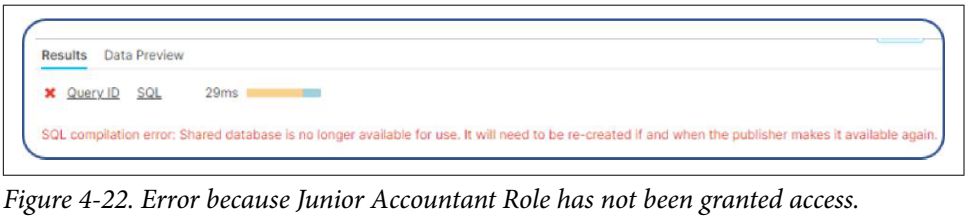



*Figure 4-22. Error because Junior Accountant Role has not been granted access.*

If the Senior Accountant ran the same query, the Sr Accountant would receive this query results shown in Figure 4-23

```
USE ROLE ACCOUNTANT_SR;
SELECT * FROM SNOWFLAKE.ACCOUNT_USAGE.QUERY_HISTORY WHERE QUERY_TYPE =
'GRANT';
```

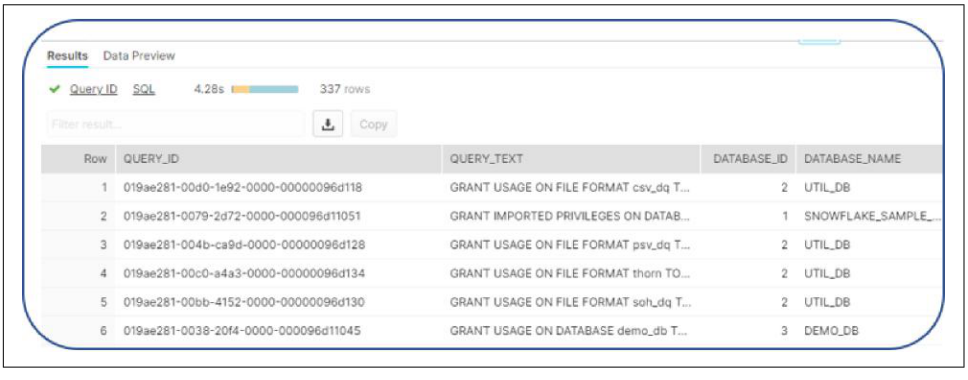



*Figure 4-23. Results Shown because Senior Account has been granted access*

Right now, our Snowflake account has no tables created by us. Whenever the SYSADMIN role creates a new table, it must assign other roles the necessary privileges for that table or else they can't access the table. However, we used a future grants option earlier to grant access to any future objects, like tables, that we created in the three schemas. Therefore, no action is needed to assign privileges on a newly created table. Let's test to see if the future grants privilege we assigned will work as intended.

First, you can see that no tables currently exist in the DB1 Schema:

```
USE ROLE SYSADMIN;
SHOW DATABASES;
USE SCHEMA DB1_SCHEMA1;
SHOW TABLES;
```

Now, we'll create a simple table and confirm that the table was created, as shown in figure 5-24.

```
CREATE OR REPLACE TABLE DB1.DB1_SCHEMA1.TABLE1 (a varchar);
INSERT INTO TABLE1 VALUES ('A');
SHOW TABLES;
```


*Figure 4-24. Confirmation that Table was Created*

Next, we'll test to see if the REPORTING role can access the table we just created. Based on the future grants privileges we assigned to the role that was then assigned to the REPORTING role, we expect that the REPORTING role should be able to access the table. This is confirmed in Figure 4-25.

```
USE ROLE REPORTING;
SELECT * FROM DB1.DB1_SCHEMA1.TABLE1;
```

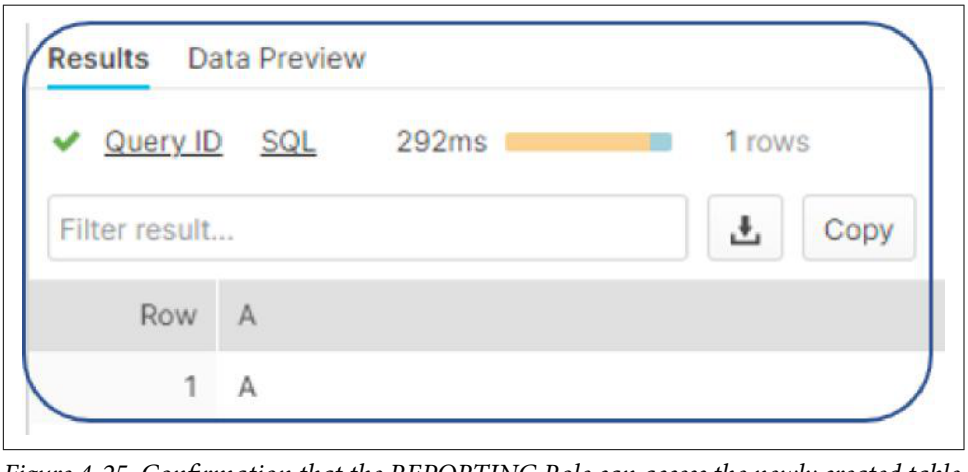



*Figure 4-25. Confirmation that the REPORTING Role can access the newly created table*

We did not grant access to DB1 to the VISUALIZER role so that role will not be able to see the table. This is evidenced in Figure 4-26.

```
USE ROLE VISUALIZER;
SELECT * FROM DB1.DB1_SCHEMA1.TABLE1;
```


*Figure 4-26. VISUALIZER Role does not have access to the newly created table.*

Here are some additional queries you can try on your own that will give you some useful information:

```
USE ROLE ACCOUNTANT_SR;
SELECT * FROM SNOWFLAKE.ACCOUNT_USAGE.GRANTS_TO_USERS;
SHOW GRANTS ON ACCOUNT;
SHOW GRANTS ON DATABASE DB1;
SHOW GRANTS OF ROLE ANALYST_SR;
SHOW FUTURE GRANTS IN DATABASE DB1;
SHOW FUTURE GRANTS IN SCHEMA DB1.DB1_SCHEMA1;
```

Any of the global privileges, privileges for account objects, and privileges for schemas can be revoked from a role. As an example, we'll have the Account Administrator grant a role to the junior analyst and then the USERADMIN will revoke that role.

```
USE ROLE ACCOUNTADMIN;
GRANT MONITOR USAGE ON ACCOUNT TO ROLE ANALYST_JR;
USE ROLE USERADMIN;
REVOKE MONITOR USAGE ON ACCOUNT FROM ROLE ANALYST_JR;
```

During a session, a user can change their role if they are assigned more than one role. When a user attempts to execute an action on an object, Snowflake compares the privileges required to complete the action against any privileges that the current role was inherently given, assigned, or was inherited. The action is allowed if the role in the session has the necessary privileges.

## User Management

A *User object* in Snowflake stores all the information about a user, including their login name, password, and defaults. A Snowflake user can be a person or a program. From previous discussion, we know that Snowflake users are created and managed by the USERADMIN system-defined role. The user name is required and should be unique when creating a user. Even though all other properties are optional, it is a best practice to include many of them. At a minimum, include some basic details and

assign an initial password which you require the user to change it at the next login. As an example:

```
USE ROLE USERADMIN;
CREATE OR REPLACE USER USER10
PASSWORD='123'
LOGIN_NAME = ABARNETT
DISPLAY_NAME = AMY
FIRST_NAME = AMY
LAST_NAME = BARNETT
EMAIL = 'ABARNETT@COMPANY.COM'
MUST_CHANGE_PASSWORD=TRUE;
```

You can add new properties or change existing user properties by using the ALTER command. For example, you may have a user that you want to grant temporary access to your Snowflake account. That can be accomplished by setting up an expiration time for the user:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET DAYS_TO_EXPIRY = 30;
```

Adding defaults for the user makes it easier for the user. You can make it so that the user has a default role or default warehouse, for example.

Adding a default warehouse for the user does not verify that the warehouse exists. We never created a Warehouse52, yet the code to assign that warehouse as a default will be executed successfully with no errors or warning:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET DEFAULT_WAREHOUSE=WH_WAREHOUSE52;
```

We can attempt to assign a default role that does exist to a user. However, if we did not previously grant that role to the user then we cannot make it the default role. In other words, setting a default role does not assign the role to the user. The same thing applies for access to a database. When we attempt to assign defaults that have not previously been assigned to a user, no warning is given but the command is not actually executed successfully:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET DEFAULT_ROLE=ANALYST_JR;
ALTER USER USER10 SET DEFAULT_NAMESPACE=DB1.DB1_SCHEMA;
```

To see for yourself, log out of your Snowflake account and log in as User10. There, you'll observe that only the Public role is available to User10, there are no warehouses

available to select, and only the three databases given to everyone are accessible to User10. This is shown in Figure 4-27.

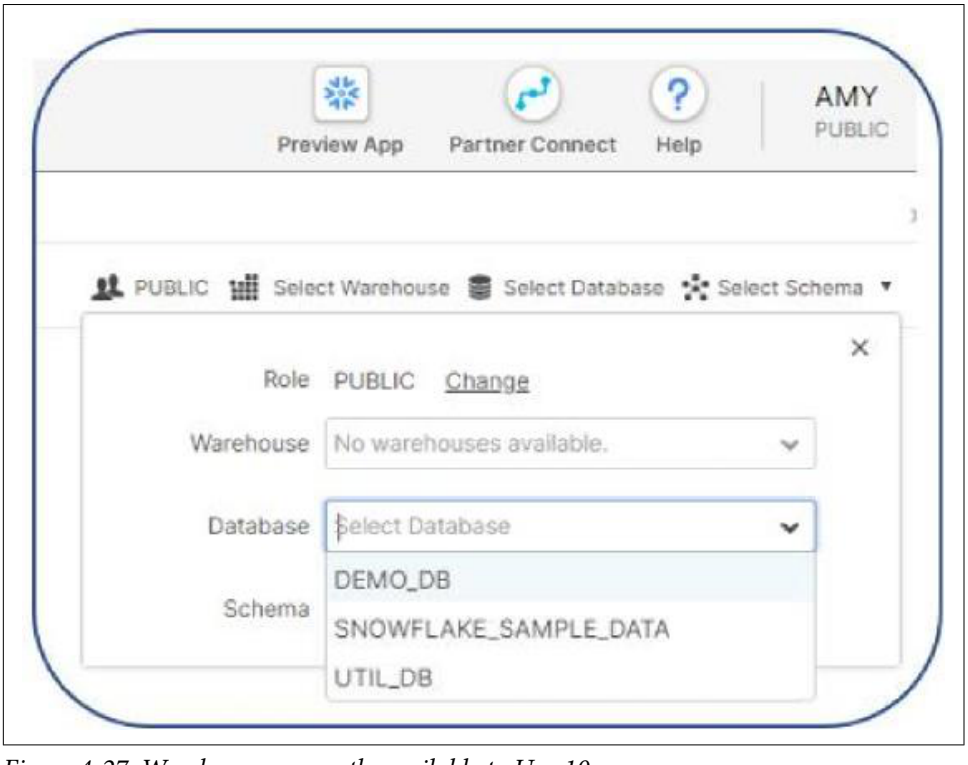



*Figure 4-27. Warehouses currently available to User10*

Be sure to log out and log back in as the Account administrator once you're done taking look around as User10.

Now we'll set some defaults for User10 that are correct, as shown in Figure 4-28. We'll log back out of our admin account and log back in as user10 once we're done.

```
USE ROLE USERADMIN;
GRANT ROLE ACCOUNTANT_SR TO USER USER10;
ALTER USER USER10 SET DEFAULT_NAMESPACE=SNOWFLAKE.ACCOUNT_USAGE;
ALTER USER USER10 SET DEFAULT_WAREHOUSE=WH_WAREHOUSE2;
ALTER USER USER10 SET DEFAULT_ROLE = ACCOUNTANT_SR;
```

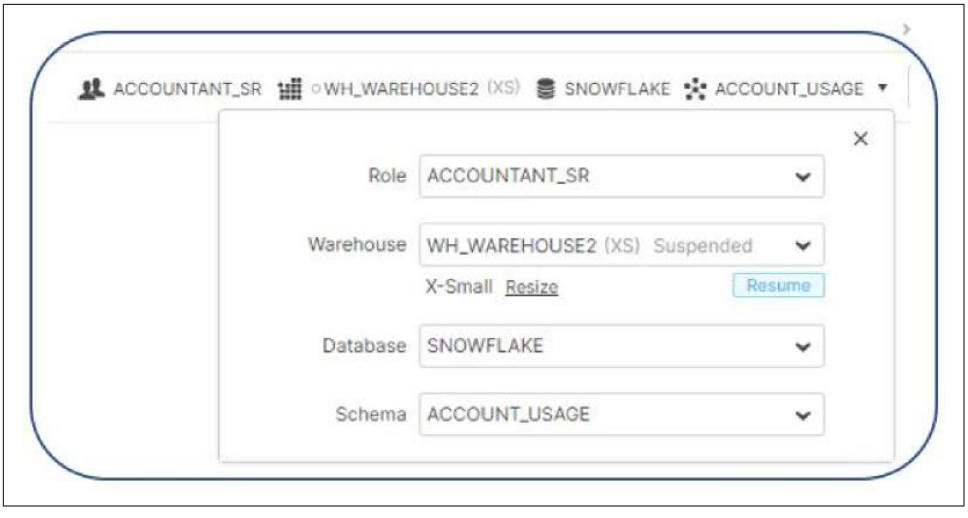



*Figure 4-28. User10 has been granted the role of ACCOUNTANT_SR and assigned certain defaults*

A common user management problem is users who are unable to log in to their account. The Snowflake system will lock out a user who failed to login successfully after five consecutive attempts. The Snowflake system will automatically clear the lock after 15 minutes. If the user cannot wait, the timer can immediately be reset:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET MINS_TO_UNLOCK=0;
```

If the user forgot the password and needs for it to be reset, reset it this way.

The original way we used to create the password will not work because '123' is not an acceptable password. If we try to use the '123' password, an error will be returned, as shown in Figure 4-29.

```
USE ROLE USERADMIN;
ALTER USER USER10 SET PASSWORD = '123'
MUST_CHANGE_PASSWORD = TRUE;
```

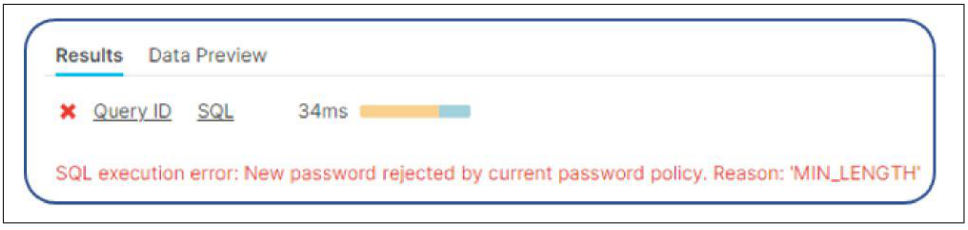



*Figure 4-29. Password rejected due to not achieving minimum length*

The password submitted by the USERADMIN to reset a forgotten password must be at least 8 characters in length, and contain at least 1 digit, 1 uppercase letter and 1 lowercase letter:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET PASSWORD = '123456Aa'
MUST_CHANGE_PASSWORD = TRUE;
```

Keep in mind that because the USERADMIN role rolls up to the SECURITYADMIN role which itself rolls up to the ACCOUNTADMIN role, the two higher roles can also run any command that the USERADMIN role can run. As an example:

```
USE ROLE SECURITYADMIN;
ALTER USER USER10 SET PASSWORD = '123456Bb'
MUST_CHANGE_PASSWORD = TRUE;
```

There may be a time when it is necessary to abort a user's currently running queries and to prevent the person from running any new queries. To accomplish this and to immediately lock the user out of Snowflake, use the following command:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET DISABLED = TRUE;
```

To describe an individual user and get a listing of all the user's property values and default values, use the DESCRIBE command. The results are shown in Figure 4-30.

```
USE ROLE USERADMIN;
DESC USER USER10;
```

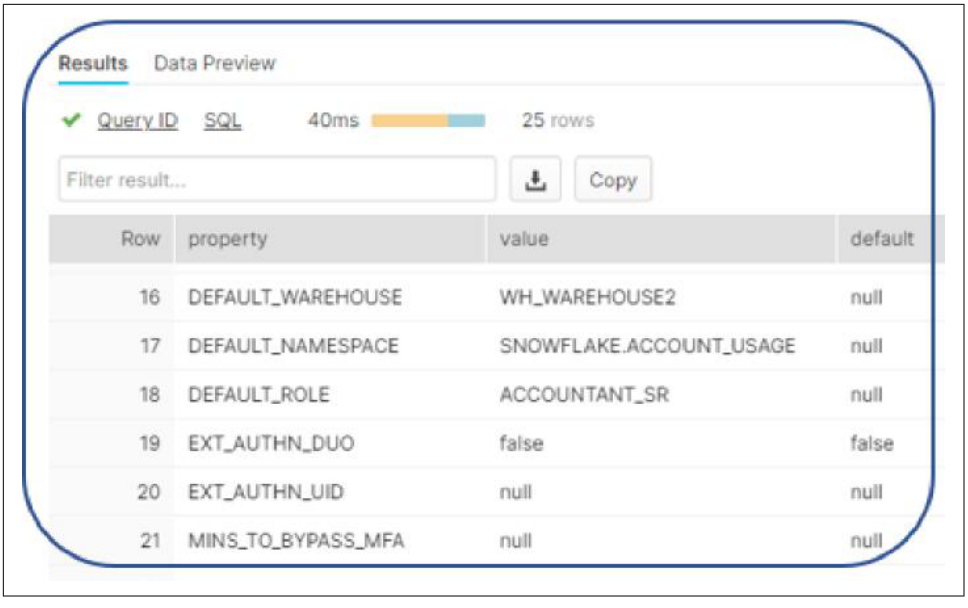



*Figure 4-30. Description of User10*

To reset one of the user's property values back to the default value, you can use this command:

```
USE ROLE USERADMIN;
ALTER USER USER10 SET DEFAULT_WAREHOUSE = DEFAULT;
USE ROLE USERADMIN;
DESC USER USER10;
```

We discovered earlier that the SECURITYADMIN role, not the USERADMIN role, has inherent privileges to see a list of all users. See Figure 4-31 for the results.

```
USE ROLE SECURITYADMIN;
SHOW USERS;
```

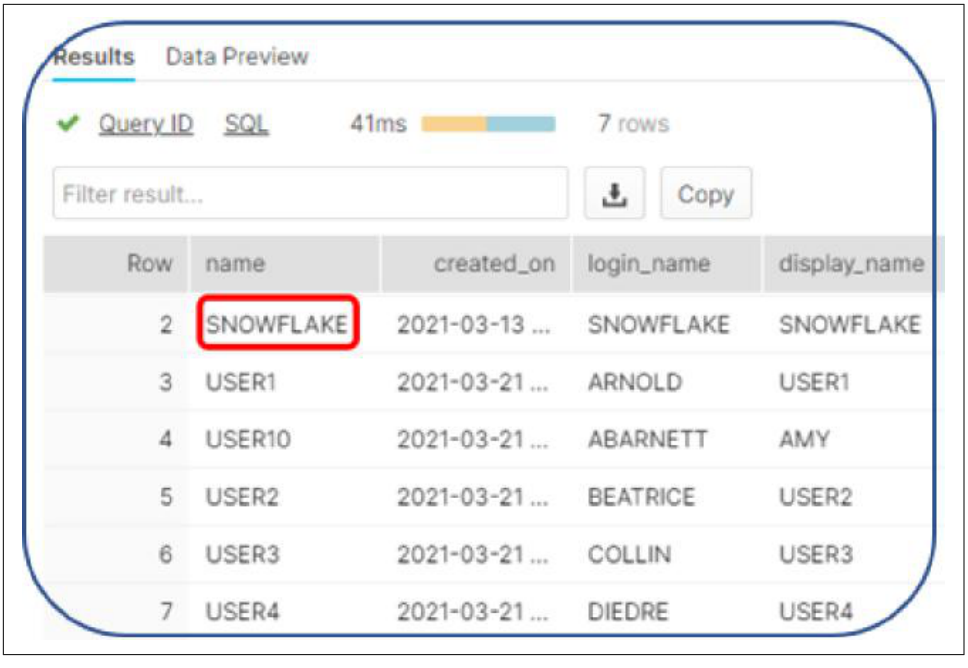



*Figure 4-31. List of Users in the Snowflake Account*

You'll notice that the list of users includes the initial user that set up the account and all the users that you created. In addition, there is one more user that came with the account. The "SNOWFLAKE" user is a special user that is only used by Snowflake support with the permission of the ACCOUNTADMIN when there is a need to troubleshoot account issues.

It is possible to delete this "SNOWFLAKE" user, but once deleted, you can't simply create another "SNOWFLAKE" user that can be used for support. Therefore, it is highly recommended that you do not delete this user.

Wildcards are supported when using the SHOW command. You can use the LIKE command with the underscore to match any single character and the percentage character to match any sequence of 0 or more characters. As an example:

```
USE ROLE SECURITYADMIN;
SHOW USERS LIKE 'USER%';
```

Just as users can be created, they can also be dropped. Notice that nothing needs to be done to anything prior to dropping the user, such as revoking their role. Just issue the DROP command:

```
USE ROLE USERADMIN;
DROP USER USER10;
```

The Account Administrator has access to a list of all users by querying the SNOWFLAKE.ACCOUNT_USAGE.USERS table, including those who have been deleted.

## Code Cleanup

Let's perform a code cleanup so that you can remove the objects in your Snowflake account in preparation for working on another chapter example.

Note that there is no need to drop objects in the hierarchy below the database before dropping the databases or to revoke the warehouse usage privileges before dropping the warehouses:

```
USE ROLE SYSADMIN;
DROP DATABASE DB1;
DROP DATABASE DB2;
SHOW DATABASES;
DROP WAREHOUSE WH_WAREHOUSE1; DROP WAREHOUSE WH_WAREHOUSE2; DROP WAREHOUSE WH_WARE-
HOUSE3; SHOW WAREHOUSES;
```

Just as the ACCOUNTADMIN had to create Resource Monitors, the same role must be used to drop Resource Monitors:

```
USE ROLE ACCOUNTADMIN;
DROP RESOURCE MONITOR RM_MONITOR1;
SHOW RESOURCE MONITORS;
```

Next, the USERADMIN role will want to drop all the roles that were created. However, not all of the roles can be dropped by the USERADMIN role. Below is a list of those roles which can be dropped by the User Administrator role:

```
USE ROLE USERADMIN;
DROP ROLE DATA_SCIENTIST;
DROP ROLE DATA_EXHANGE_ASST;
DROP ROLE ANALYST_SR;
DROP ROLE ANALYST_JR;
DROP ROLE DATA_EXCHANGE_ASST;
DROP ROLE ACCOUNTANT_SR;
DROP ROLE ACCOUNTANT_JR
DROP ROLE PRD_DBA;
DROP ROLE DATA_ENGINEER;
DROP ROLE DEVELOPER_SR;
DROP ROLE DEVELOPER_JR;
DROP ROLE LOADER;
DROP ROLE VISUALIZER;
```

```
DROP ROLE REPORTING;
DROP ROLE MONITORING;
DROP ROLE RM1_MODIFY;
DROP ROLE WH1_USAGE;
DROP ROLE WH2_USAGE;
DROP ROLE WH3_USAGE;
DROP ROLE DB1_MONITOR;
DROP ROLE DB2_MONITOR;
DROP ROLE WH1_MONITOR;
DROP ROLE WH2_MONITOR;
DROP ROLE WH3_MONITOR;
DROP ROLE RM1_MONITOR;
SHOW ROLES;
```

While we used the USERADMIN role to drop most of the custom roles, I mentioned that we cannot drop all of the custom roles. Let's see what happens if we attempt to drop this custom role using the USERADMIN role.

```
USE ROLE USERADMIN;
DROP ROLE DB1_SCHEMA1_READONLY;
```

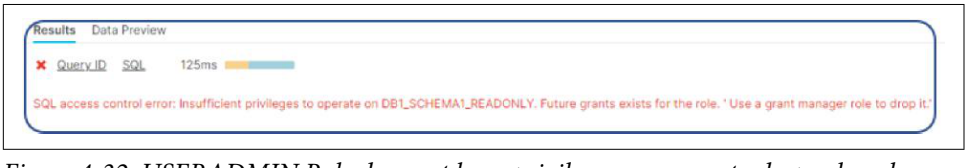



*Figure 4-32. USERADMIN Role does not have privileges necessary to drop roles where future grants have been assigned*

We see that for any object for which future grants were assigned, the USERADMIN role did not have the necessary privileges to drop the role, as shown in Figure 4-32. Instead, a SECURITYADMIN role or higher is required to drop the roles. Let's use the SECURITYADMIN role to finish dropping the roles and confirm that all custom roles have now been dropped:

```
USE ROLE SECURITYADMIN;
DROP ROLE DB1_SCHEMA1_READONLY;
DROP ROLE DB1_SCHEMA1_ALL;
DROP ROLE DB2_SCHEMA1_READONLY;
DROP ROLE DB2_SCHEMA1_ALL;
DROP ROLE DB2_SCHEMA2_READONLY;
DROP ROLE DB2_SCHEMA2_ALL;
SHOW ROLES;
And, now, we are able to drop the users we created:
USE ROLE USERADMIN;
DROP USER USER1;
DROP USER USER2;
DROP USER USER3;
DROP USER USER4;
```

We can confirm that all the users have now been dropped:

```
USE ROLE SECURITYADMIN;
SHOW USERS;
```

## Exercises to Test Your Knowledge

The following exercises are based on the coverage in this chapter about user management and object security.

1. How would you define inherent privileges? Give a few examples.
2. Can you name all the Snowflake system-defined roles? To which of the system-defined roles should most custom roles be assigned to in the role hierarchy?
3. What are some of the important considerations to keep in mind when assigning defaults, such as default role or default warehouse, to a user?
4. What is one thing that an Account Administrator can do that no other role can ever do?
5. Can you name the privileges a role needs in order to view the contents of a table?
6. What is unique about the SNOWFLAKE database that is included in the account?

Solutions to these exercises are available in Appendix A.

# CHAPTER 5
# Visualizing Data for Better Insights

### A Note for Early Release Readers

With Early Release ebooks, you get books in their earliest form—the author's raw and unedited content as they write—so you can take advantage of these technologies long before the official release of these titles.

This will be the 11th chapter of the final book.

If you have comments about how we might improve the content and/or examples in this book, or if you notice missing material within this chapter, please reach out to the editor at *mcronin@oreilly.com*.

Snowsight replaced the Snowflake SQL Worksheet as the new Snowflake web user interface. In large part, Snowsight has increased Snowflake's usability by providing access to worksheet history and by providing the ability to switch between Snowflake accounts. Additionally, Snowsight's SQL query formatting, UI keyboard shortcuts, and autocomplete allow Snowflake users to write queries more efficiently. Thus, Snowsight has become a valuable data visualization tool with the ability to collaborate with other Snowflake users.

In this chapter, we will work together through the following topics. The code in the chapter is also available on Github.

- How to Access Snowsight
- Navigating Snowsight and Data Sampling
- Improved Productivity
- Visualization

- Collaboration
- Test Your Knowledge

## How to Access Snowsight

If you are not currently logged in as an ACCOUNTADMIN, be sure to change your role to ACCOUNTADMIN. You can access Snowsight in one of two ways. In the Classic Console Web Interface, you click on the "Preview App" button in the top right corner of the screen (Figure 5-1) or you can log directly into Snowsight: https://app.snowflake.com/.

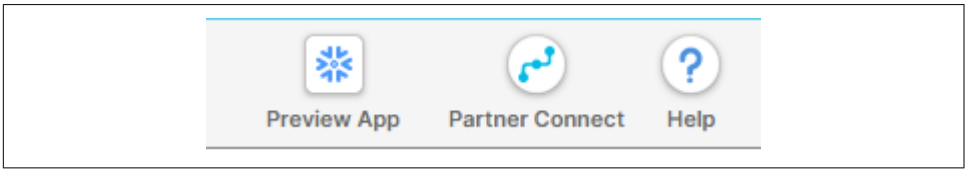



*Figure 5-1. Classic Console Web Interface showing the "Preview App" button*

Once inside Snowsight, "Worksheets" is the default tab (Figure 5-2). You can also click on some of the different tabs, including the "Data" tab and the "Compute" tab to see some of the available options. As we will see later, the "Databases" sub-tab will display the databases available to you within your access rights.

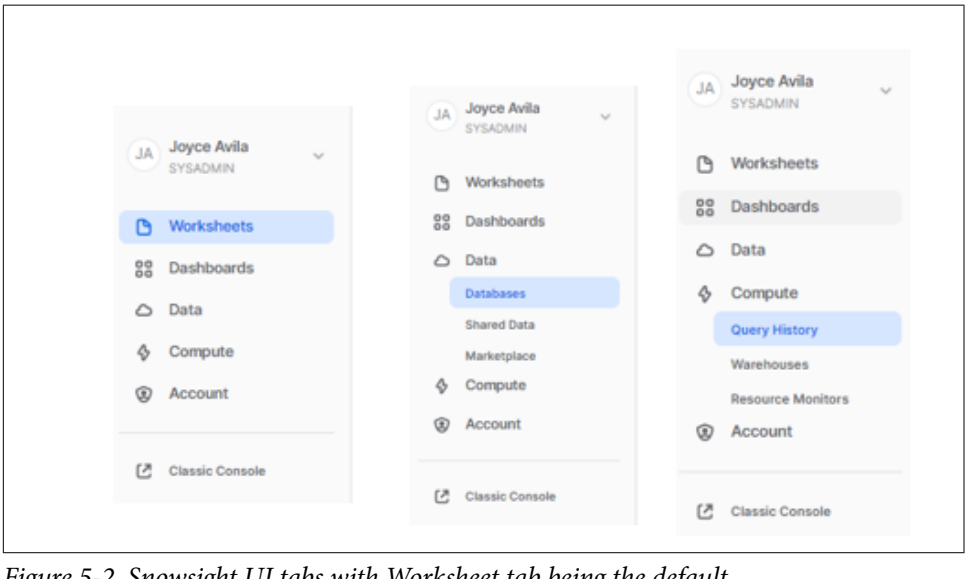



*Figure 5-2. Snowsight UI tabs with Worksheet tab being the default*

If you have been working in the Classic Web Interface, you'll be presented the option to import your Worksheets when you first come over into Snowsight (Figure 5-3).

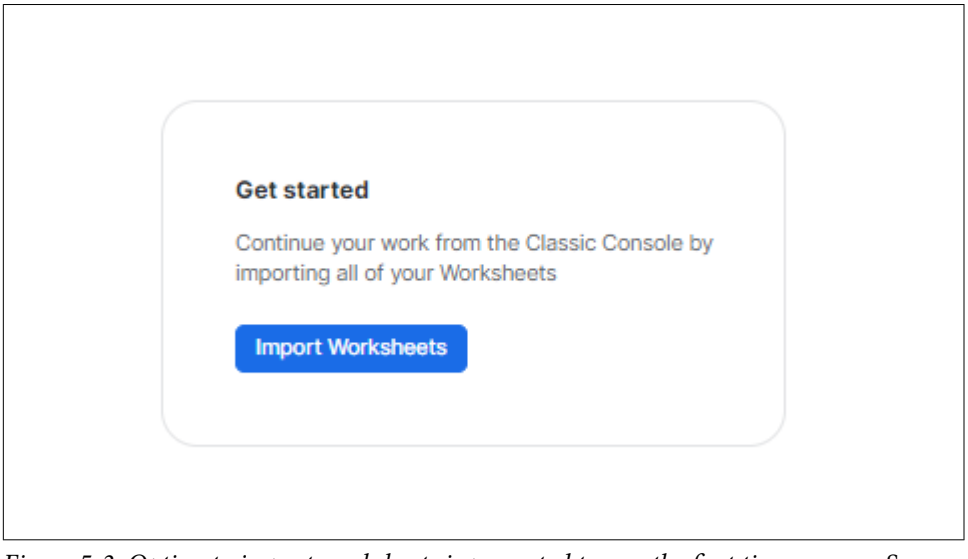



*Figure 5-3. Option to import worksheets is presented to you the first time you use Snowsight*

If you import a Worksheet from the Classic UI, a new timestamped folder will be created (Figure 5-4).

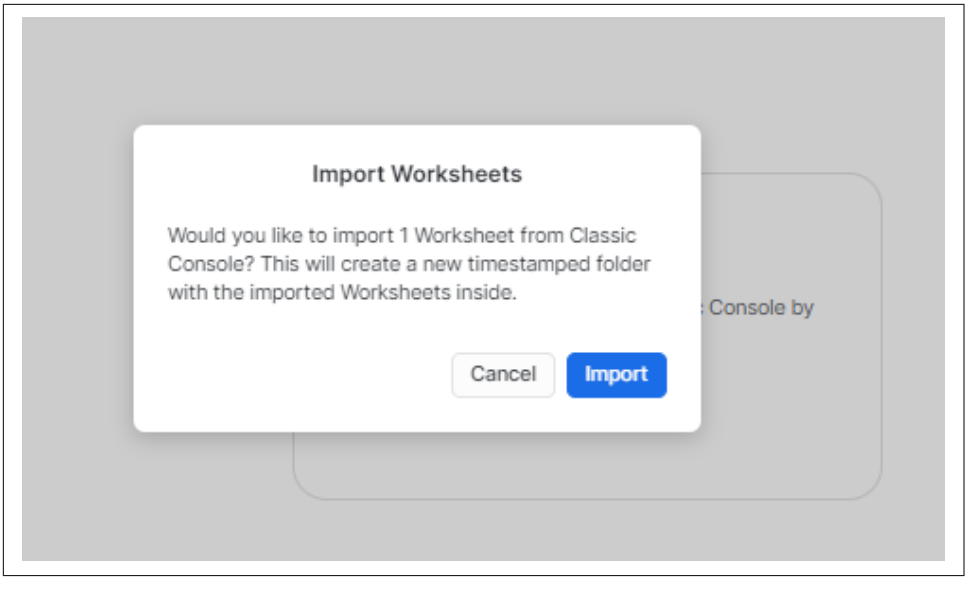



*Figure 5-4. Importing worksheets from the Classic Console will create a new timestamped folder*

If you click on the Worksheets tab and then "Folders", you will see the new folder that was created (Figure 5-5).

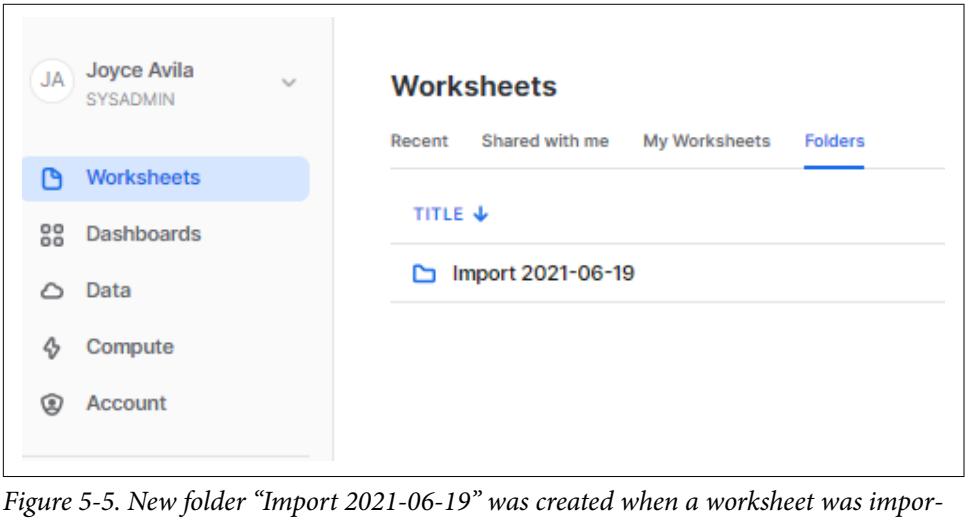



*Figure 5-5. New folder "Import 2021-06-19" was created when a worksheet was imported*

As you navigate around Snowsight and do the exercises in this chapter, one of the things you will notice is that everything in Snowsight is auto saved.

# Navigating Snowsight and Data Sampling

In this section, we'll discover how to navigate in Snowsight while we learn about data sampling in Snowflake. Sampling data is helpful for both productivity and visualization purposes. After loading large datasets, ETL developers or software engineers who are responsible for loading data can scan a sample of the data to ensure that nothing unusual stands out. Likewise, business analysts can view a sample of unfamiliar data as a first step in exploring the data and auditors can obtain a sample of the data on which to perform analysis. There are limits to the number of records that can be used for Snowsight charts and dashboards.

Sampling allows you to create a dashboard with a limited subset of the data that closely resembles the full data set. Sampling returns a subset of rows from a specified table. The number of rows returned from sampling a Snowflake table depends on whether you choose to return rows based on a specific number or return a certain percentage of table rows:

*Number of rows*
: It is possible to sample a fixed number of rows specified in the query. If you want a data sample rather than all the data rows returned, be sure to specify the number of rows for sampling to be less than the total number of rows in the table. The number of rows can be any integer between 0 and one million. Note that the Bernoulli sampling method is used when you sample by number of rows and System/Block and Seed are not supported in this case. Bernoulli sampling is a sampling process where each row would have an equal chance of being selected.

*Probability*
: You can sample a portion of the table with the exact number of rows returned dependent on the size of the table. It is possible to specify a seed, making the sampling deterministic, and then state the specified probability for a particular row being included in the sample. Either the Bernoulli or System sampling method can be used. System sampling is often faster than Bernoulli sampling, but the sample could be biased, especially for small tables. If not specified, Bernoulli is the default sampling method.

Keywords that can be used interchangeable include: "SAMPLE" and "TABLESAMPLE", "BERNOULLI" and "ROW", "SYSTEM" and "BLOCK", and "REPEATABLE" and "SEED".

To prepare for our first chapter exercise, let's create a new folder. On the top right corner, click on the ellipsis and then click on "New Folder" (Figure 5-6).

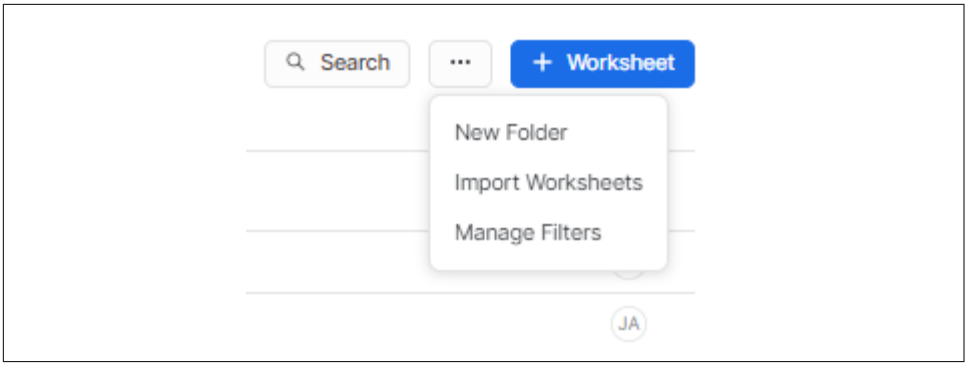



*Figure 5-6. Clicking on the ellipsis offers choices for the user, including creating a new folder*

Name the new folder "Sampling" and then click on (+ Worksheet) to create a new worksheet (Figure 5-7).

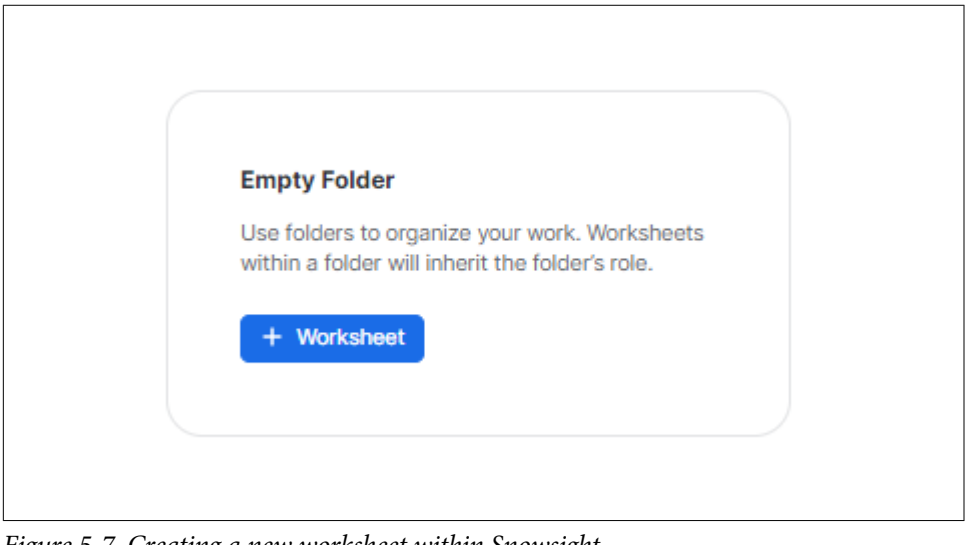



*Figure 5-7. Creating a new worksheet within Snowsight*

You should now see where you can begin entering in your query to obtain a sample (Figure 5-8).


*Figure 5-8. Entering a Query in Snowsight*

First, we have to select the database and schema (Figure 5-9). To the right of "No Database selected", click on the drop-down arrow and select the database "SNOWFLAKE_SAMPLE_DATA".

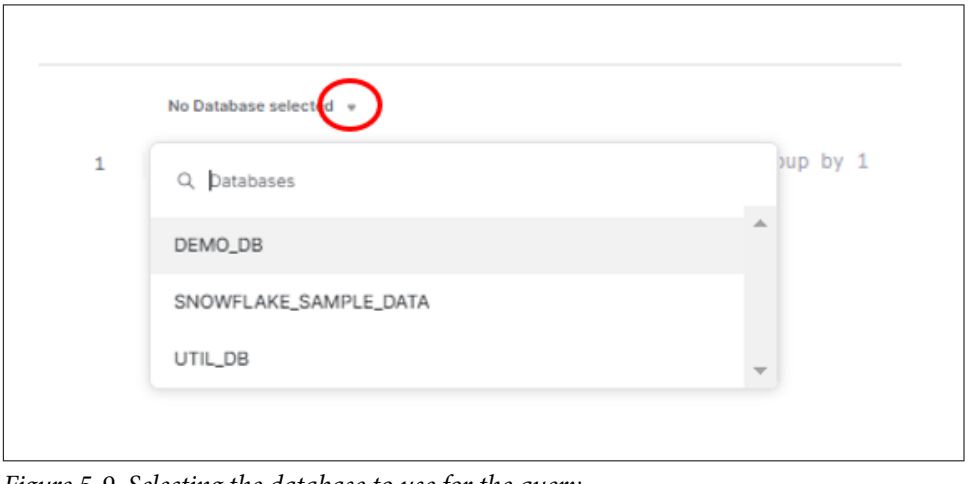



*Figure 5-9. Selecting the database to use for the query*

Next, select the TPCDS_SF100TCL schema. You can also open the schema and the tables on the left so you can see the tables you will have to work with (Figure 5-10).

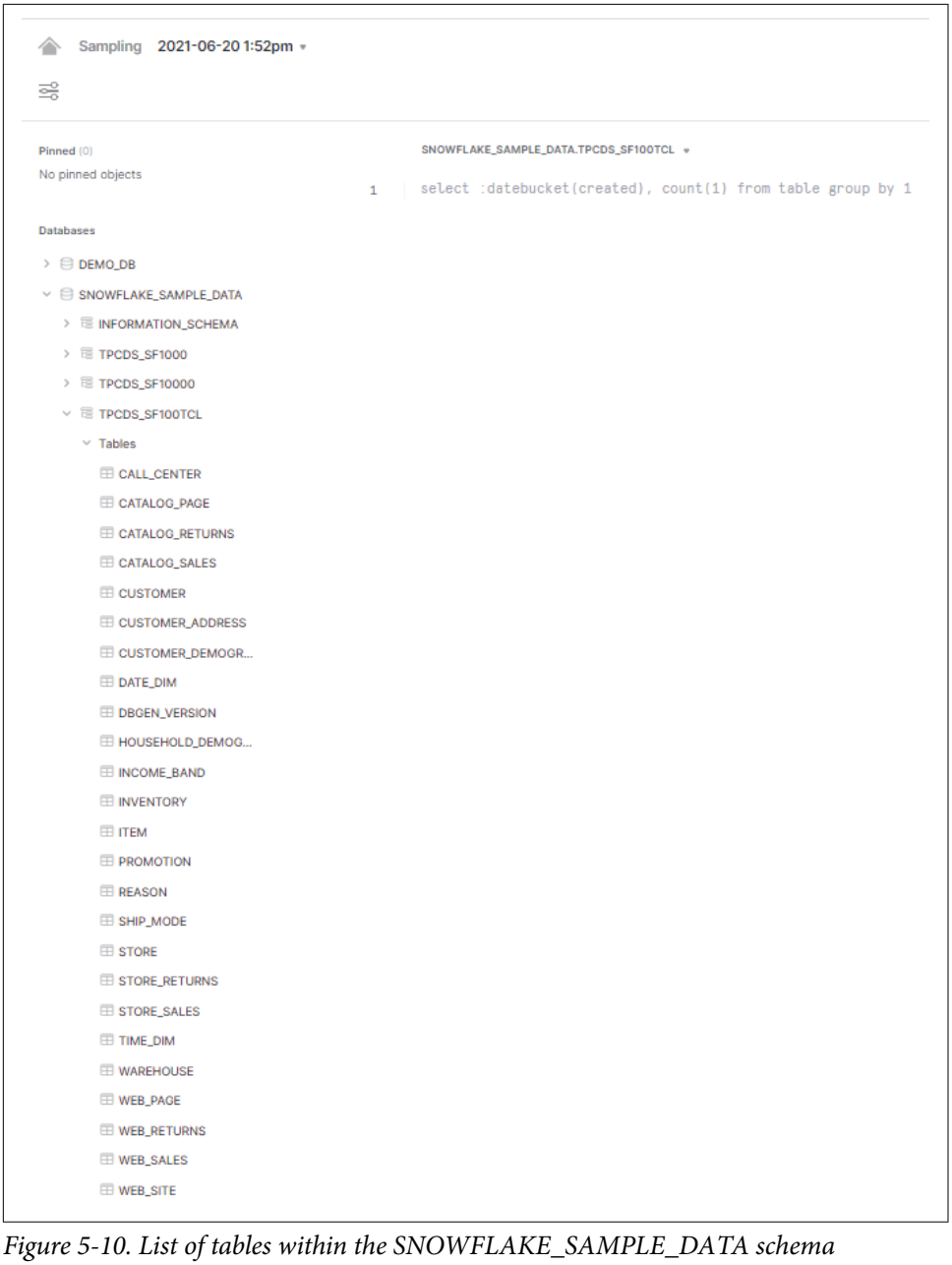



*Figure 5-10. List of tables within the SNOWFLAKE_SAMPLE_DATA schema*

Click on the "STORE_SALES" table and you'll see a preview that shows there are more than 288 billion rows in the table. Click on the magnifying glass on the right

side (Figure 5-11) and Snowflake will return the first 100 rows for you to view. Scan through the rows to get a sense of the data that exists.

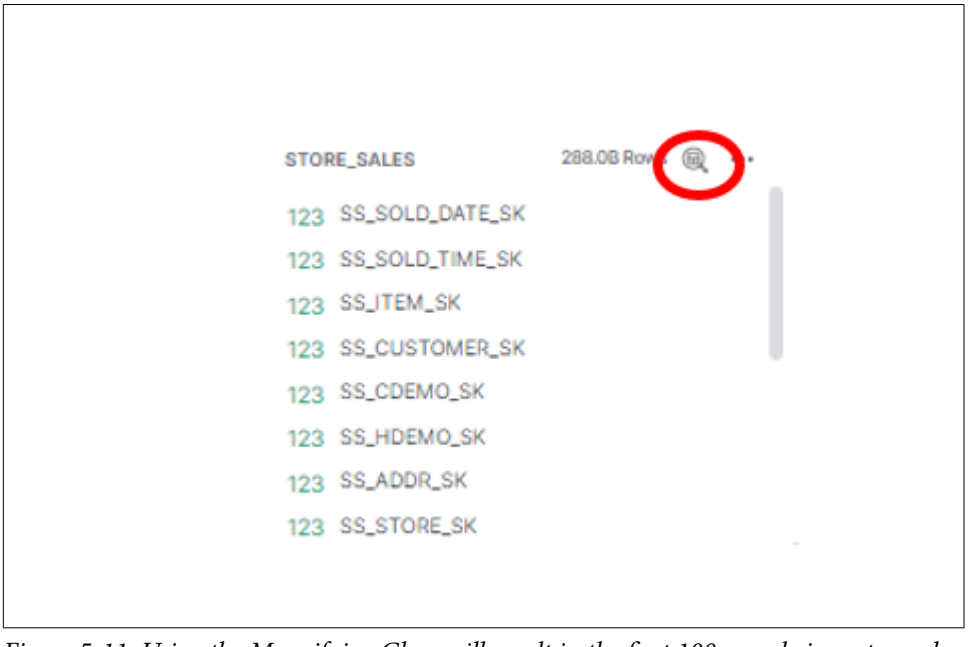



*Figure 5-11. Using the Magnifying Glass will result in the first 100 rows being returned*

Once you have entered your SQL statement to obtain 100 records by limiting the number of rows returned, position your cursor either above or within the query text in the text editor. Next, click the Run button which is a blue arrow within a circle located at the top right of the screen, or type [CMD] + [RETURN] for Mac or [CTRL] + [ENTER] for Windows.

```
Select * from store_sales limit 100;
```

When you scroll down through the results, you'll see that exactly 100 rows were returned. They are different from the 100 rows that you previewed. Run the query again and you'll notice that exactly the same 100 records are returned. Will the same thing happen when we use sampling? Let's see. Query the same table to have 100 rows returned but, this time, use "sample" instead of "limit".

```
Select * from store_sales sample (100 rows);
```

Sample query results are unique in that the results are not cached. As a result, you'll receive a different subset of 100 records if you run the same query again. Try running the query again and see what happens.

One of the things you'll notice about Snowsight that is different from the Classic UI is that there are four buttons below the query and just to the right of the object listings. Currently there are three of the buttons highlighted in blue (Figure 5-12).

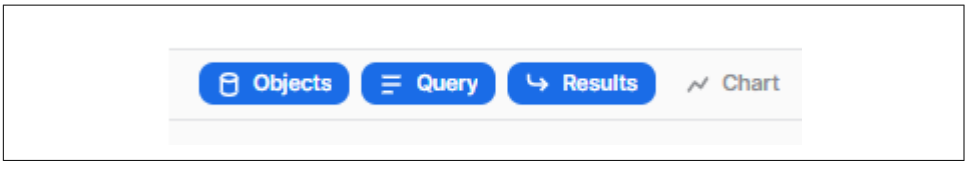



*Figure 5-12. Four buttons in Snowsight just below the query and to the right of the object listings*

Deselect each of the three buttons one at a time to see what happens. Notice what happens to your workspace area as you deselect and then reselect each one. The "Objects" button determines whether you see the objects to the left of your screen. You can deselect the "Query" button which gives you a full screen view of the results or you can deselect the "Results" button to get a full screen view of the worksheet queries. If you select "Chart" button, the "Results" button is deselected. Changing up the Snowsight viewing area allows you to customize the Snowflake UI and there are also many other improvements Snowflake has made in their new web UI.

In the next section, we'll take a look at new Snowsight features that improve user productivity, then we'll look at Snowsight charts and dashboards, and finally we'll look at some new collaboration features.

# Improved Productivity

First off, you'll appreciate the many improvements that come with Snowsight, if you've been working in the Snowflake Classic UI. Snowsight provides automatic contextual statistics, script version history, worksheet folder structures, shortcuts and much more.

## Using Contextual Suggestions from Smart Autocomplete

You may have noticed when we were writing our sampling query that the Snowflake smart autocomplete gave you contextual suggestions. Indeed, Snowflake showed you your choices before you could complete the name of the table (Figure 5-13). And if you were to begin typing in a function name, Snowflake will give you information about the parameters needed as well as link to the Snowflake docs.

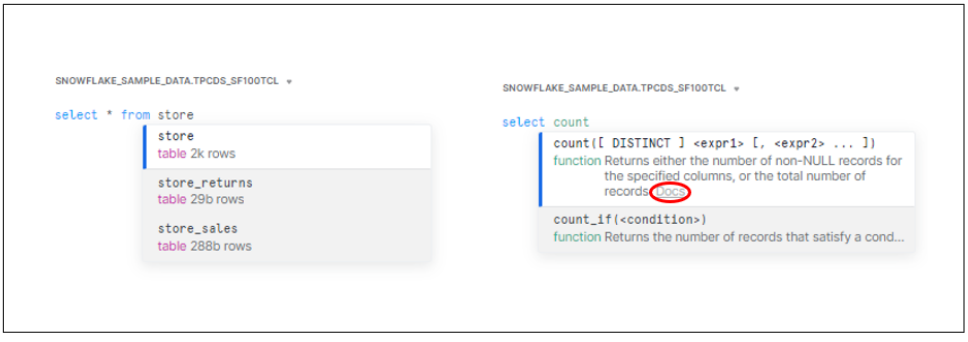



*Figure 5-13. Snowsight contextual suggestions from smart autocomplete*

## Formatting SQL

Snowsight gives you the ability to neatly format your SQL code. Use the drop-down menu to select "Format query" to have your SQL query reformatted (Figure 5-14).

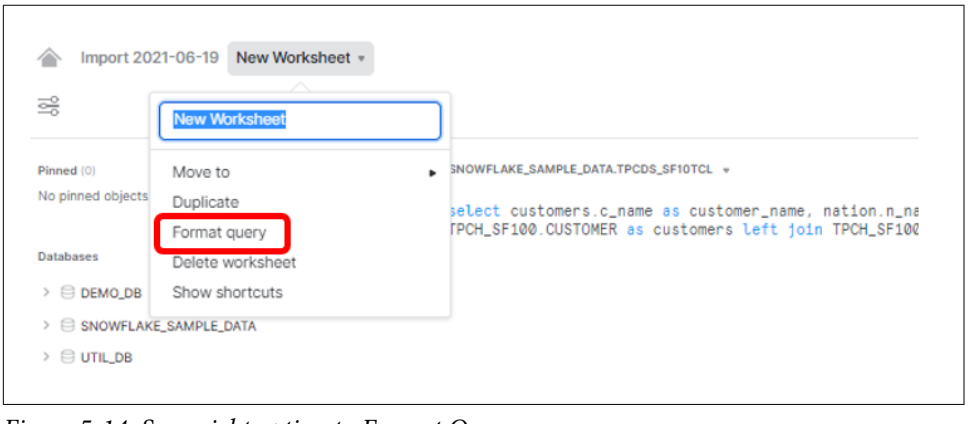



*Figure 5-14. Snowsight option to Format Query*

It is no longer necessary to spend time formatting your messy code before sharing with others or collaborating on your dashboards. The "Format query" option takes care of that for you. Whereas the original query was two long lines of code; the reformatted query is perfectly formatted (Example 11-1).

*Example 5-1. Formatted Query*

```
select
        customers.c_name as customer_name,
        nation.n_name as nation_name,
        customers.c_acctbal as account_balance,
        customers.c_mktsegment as market_segment
from
```

```
        TPCH_SF100.CUSTOMER as customers
        left join TPCH_SF100.NATION as nation on customers.c_nationkey =
nation.n_nationkey
where
        nation.n_nationkey = 24;
```

You use the "Format query" option to clean up any messy formatting before you share your SQL code or collaborate on visualizations together.

## Previewing Data Quickly

In the previous section, we took advantage of being able to preview the first 100 records of a table by clicking on the magnifying glass (Figure 5-15).

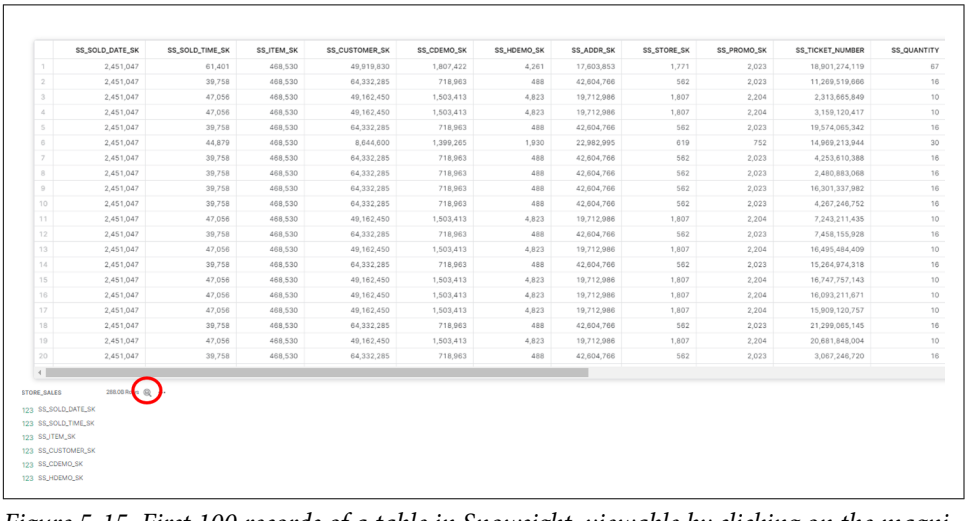



*Figure 5-15. First 100 records of a table in Snowsight, viewable by clicking on the magnifying glass*

An active warehouse is required to preview data.

## Using Shortcuts

You'll find that there are a number of shortcut commands in Snowsight commands. Click on the dropdown arrow beside the name of the worksheet and the click on "Show Shortcuts" to access those commands (Figure 5-16).

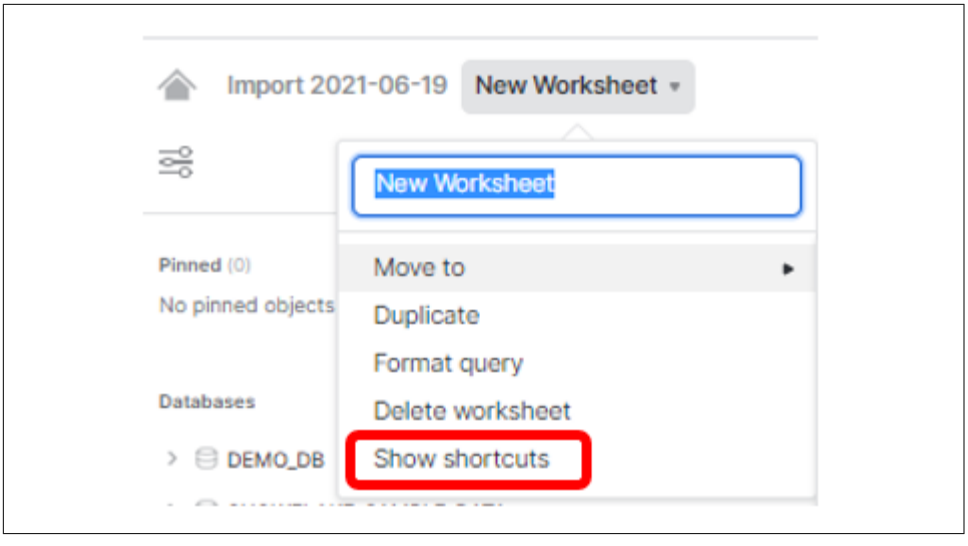



*Figure 5-16. Option to Show Shortcuts is available in Snowsight*

After you click enter, you'll be shown the list of shortcuts (Figure 5-17).

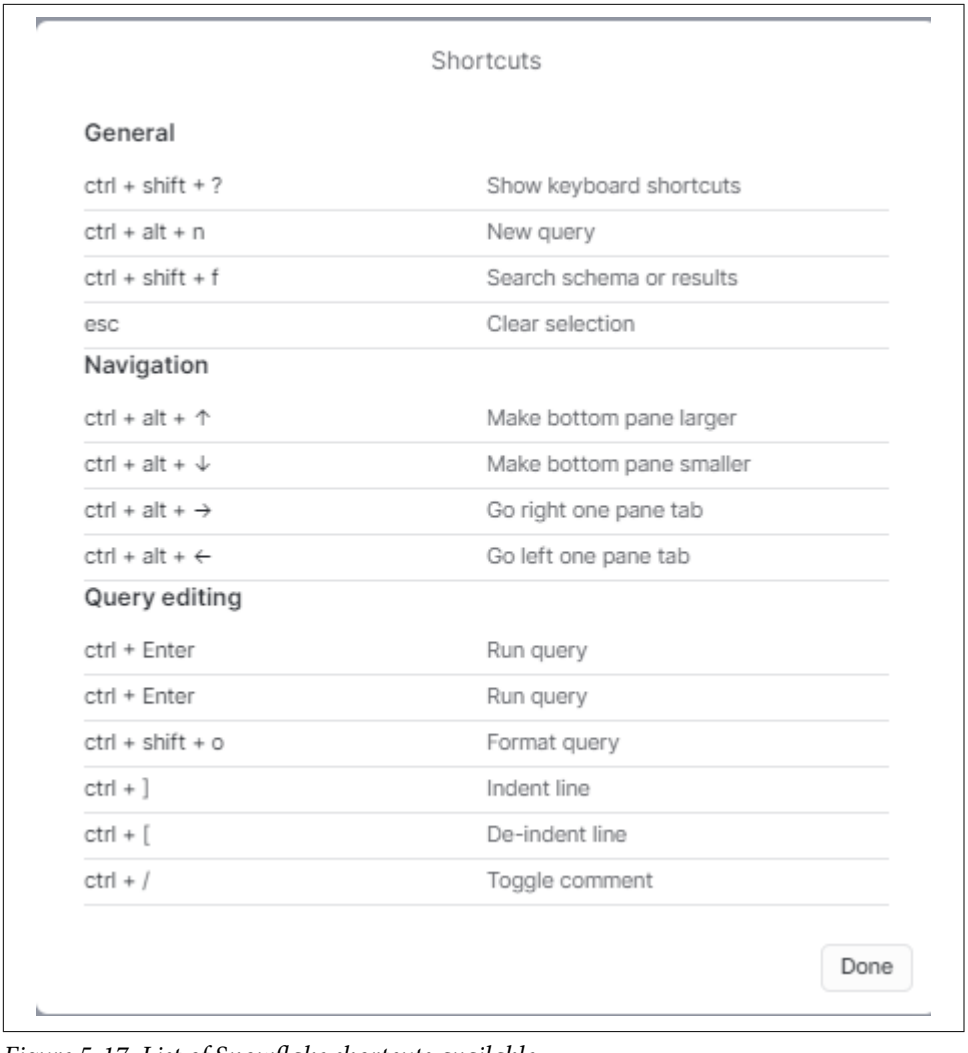



*Figure 5-17. List of Snowflake shortcuts available*

## Using Automatic Statistics and Interactive Results

Snowsight uses metadata proactively to provide expedited fast interactive results no matter how many rows are returned in query results. As you load and query the data, Snowflake puts all the rich metadata that is stored behind the scenes into a GUI interface so that you can start to understand some of the trends in your data and/or catch any errors early on. For example, you can tell right away whether there are a lot of null values in a field. This is especially advantageous to ETL engineers who are then able to detect loading errors or gaps in the data being received.

In addition to the Snowsight automatic contextual statistics which tell you how many rows are filled, you'll also see histograms for all date, time, and numeric columns, and frequency distributions for categorical columns. Additionally, Snowflake provides email domain distributions for email columns and key distributions for JSON objects.

Let's take a look at some of Snowsight's automatic statistics and interactive results. Run a select * statement on the CATALOG_RETURNS table and limit the results to 500,000. You'll see the statistics to the right of the results (Figure 5-18).


*Figure 5-18. Query Details and Statistics*

The statistics results are interactive. If you click on the statistics for column CR_CATALOG_PAGE_SK, you'll see that 98% of the records have a page SK value (Figure 5-19). You can also see the rank of values.

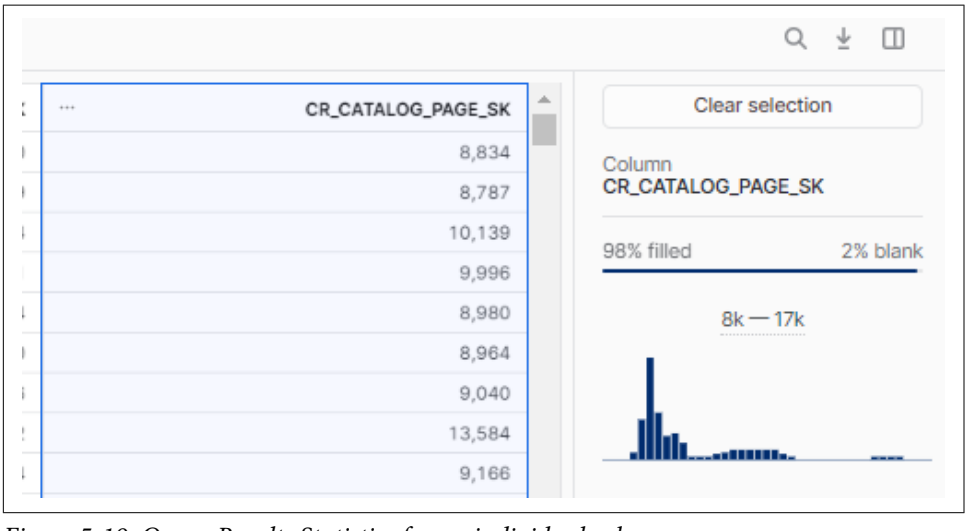



*Figure 5-19. Query Results Statistics for an individual column*

Rather than having to write individual queries or change over to a data science or visualization tool to find out how complete the data is and what are the distinct values or date ranges for each column, the user can now use Snowsight's automatic statistics and interactive results.

## Accessing Version History

The current worksheet is automatically saved each time a SQL statement is run in a Snowsight worksheet. If a statement or script is re-executed multiple times, the version history will be available. The various versions can be accessed by accessing the drop-down menu on the right side of the screen where it is shown when the last time the worksheet was updated (Figure 5-20).

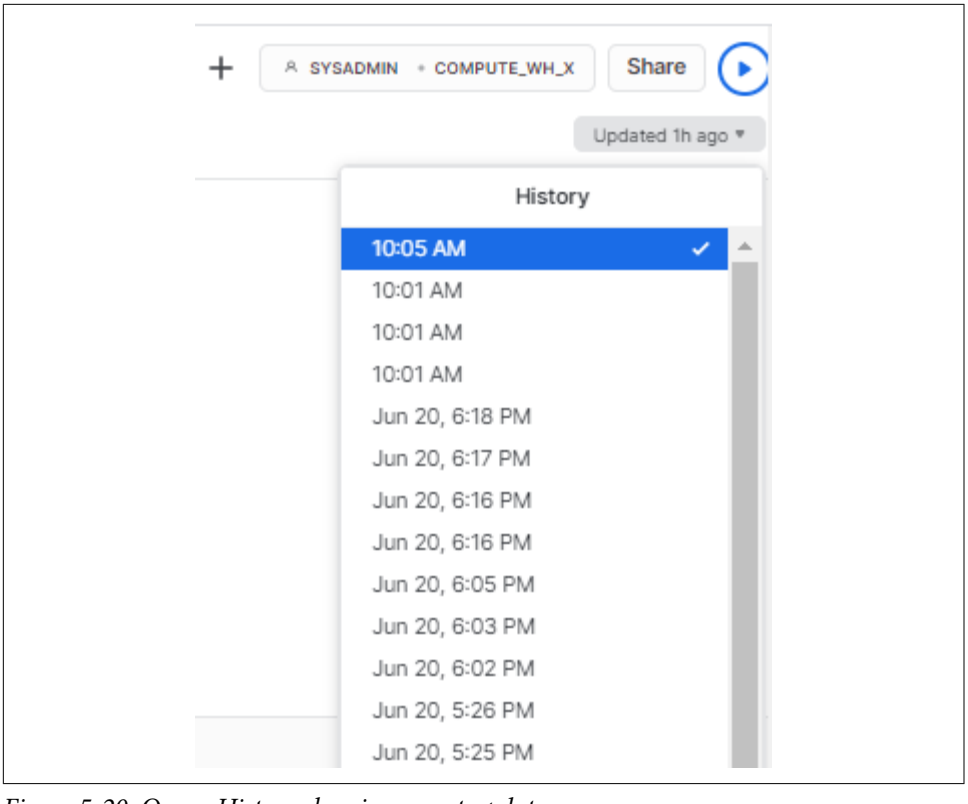



*Figure 5-20. Query History showing recent updates*

# Visualization

It is incredibly helpful to have the ability to preview 100 rows of the data and especially to be able to use automatic statistics and interactive results to quickly learn much about the data. However, the metadata isn't enough. We'll want to use the new Snowsight visualization tools to get a more complete story about the data.

Data visualization makes it much easier to identify trends, patterns, and outliers and to discover insights within complex data. Information displayed in a visual context, such as a graph or a map, is a more natural way for the human mind to comprehend large amounts of data. Business Intelligence tools such as Tableau and Power BI are used for corporate reporting and for building complex dashboards where many users are consumers of a particular dashboard.

Sometimes, individuals or small groups of users in an organization just need to undertake ad-hoc data analysis, perform data validation while loading data, or quickly create simple charts and dashboards that can be shared and explored together

as a team. For those use cases, Snowflake's Snowsight visualization tool is a great choice.

## Creating a Dashboard and Tiles

Tiles are created from within a dashboard. Let's begin by creating a dashboard where we can create our tiles. You will want to click on the folder. In this case, the folder name is "Sampling" (Figure 5-21).

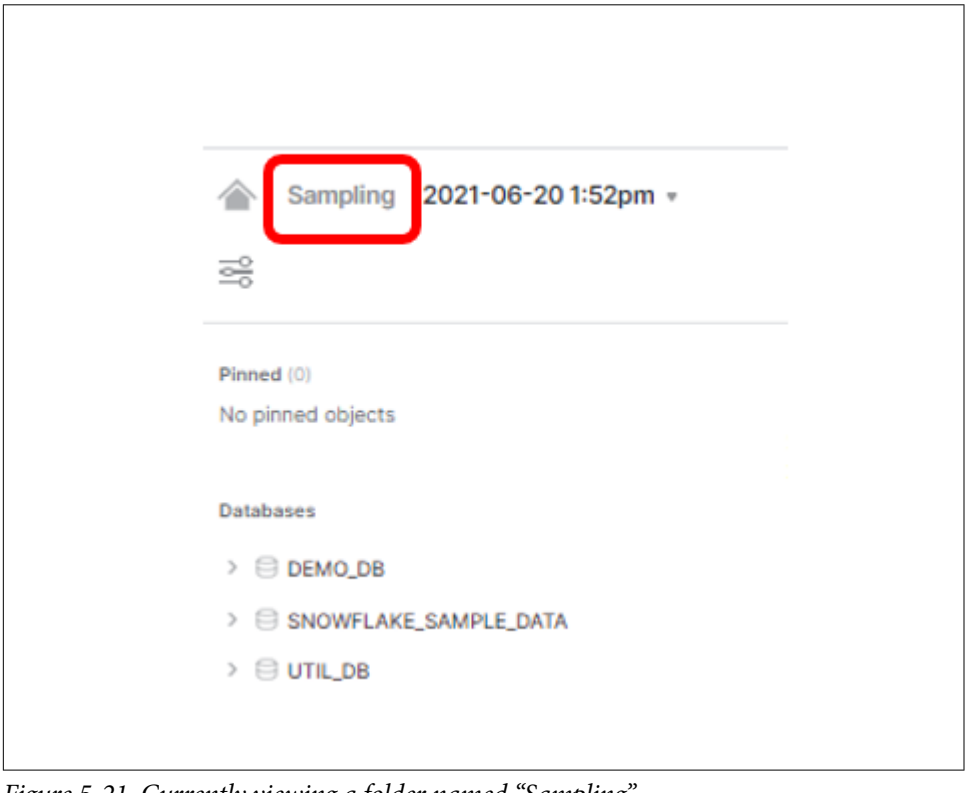



*Figure 5-21. Currently viewing a folder named "Sampling"*

Then click on Dashboards to the left and "+ Dashboard" to the right to create a new dashboard (Figure 5-22).

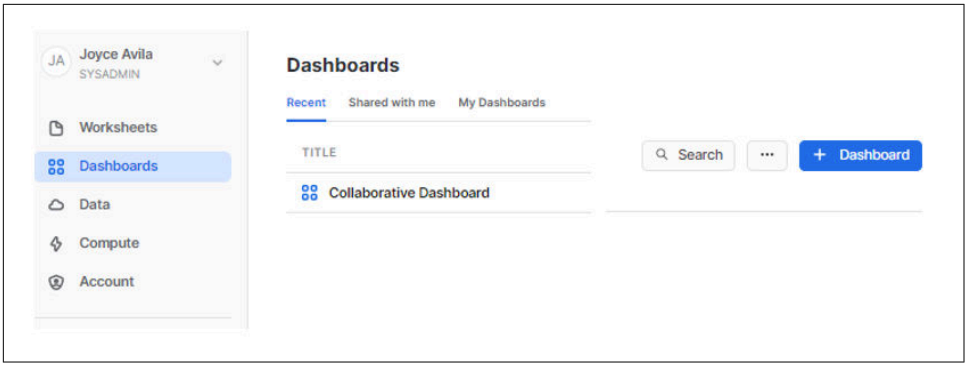



*Figure 5-22. Creating a new Dashboard in Snowsight*

Give the dashboard a name and click on the "Create Dashboard" button and then "+ New Tile" button (Figure 5-23).

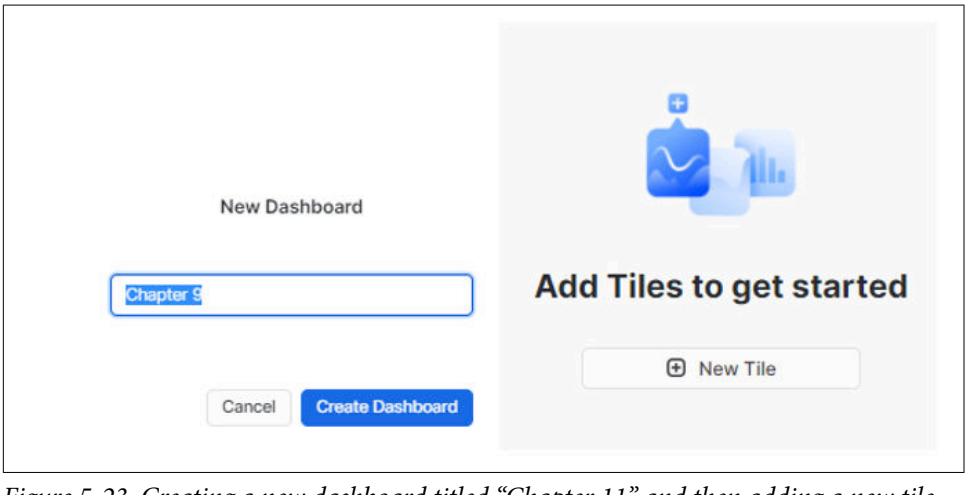



*Figure 5-23. Creating a new dashboard titled "Chapter 11" and then adding a new tile*

Just as before, select the database and schema (Figure 5-24).

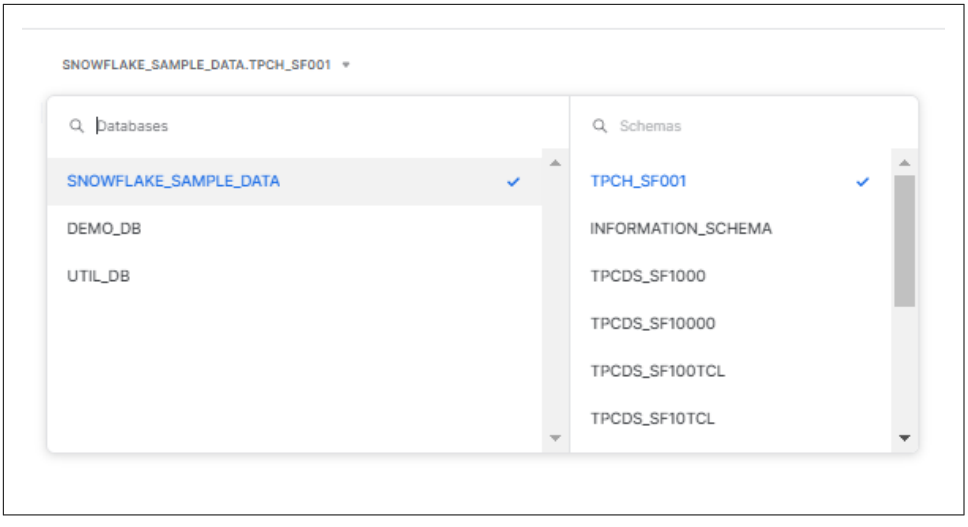



*Figure 5-24. Selecting the database and schema for the new Chapter 9 dashboard*

Click on the Query button and you'll see all the database tables to the right. Click on any of the tables and they'll be pinned to your workspace (Figure 5-25). If there is any table you no longer want to pin, just click on the pushpin and the table will be removed from the workspace. You'll also notice that the pushpin next to the table name, located on the right side of the screen, is no longer there.

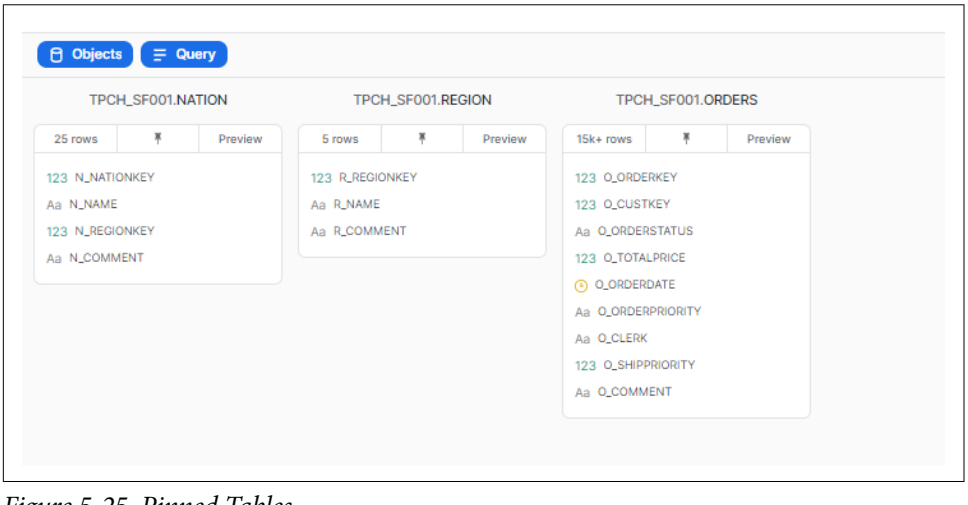



*Figure 5-25. Pinned Tables*

## Working with Chart Visualizations

We'll start with a basic query.

```
Select * from TPCH_SF1.LINEITEM limit 100000
```

Click on the Chart button at the bottom to see the chart. It will default to a line chart (Figure 5-26).

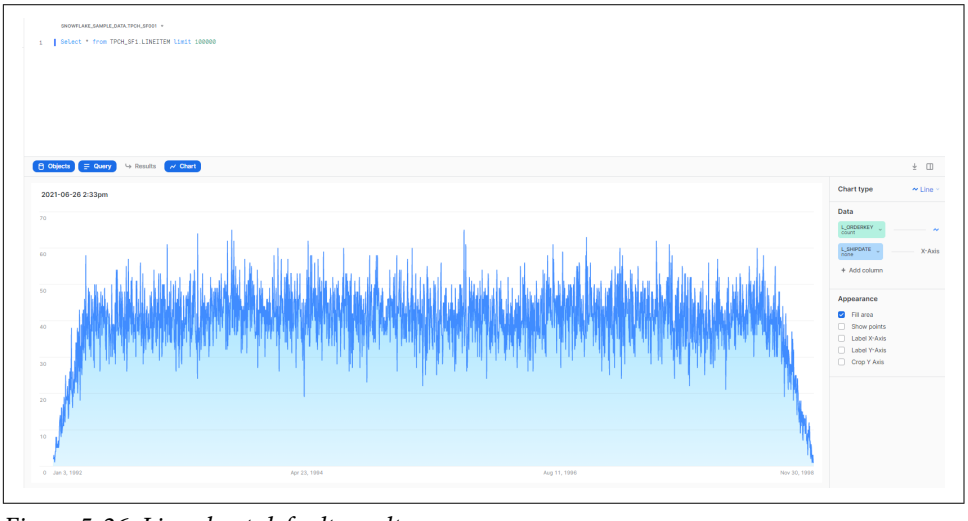



*Figure 5-26. Line chart default results*

On the right, there is a chart drop-down menu (Figure 5-27). Select Bar chart and see what happens.

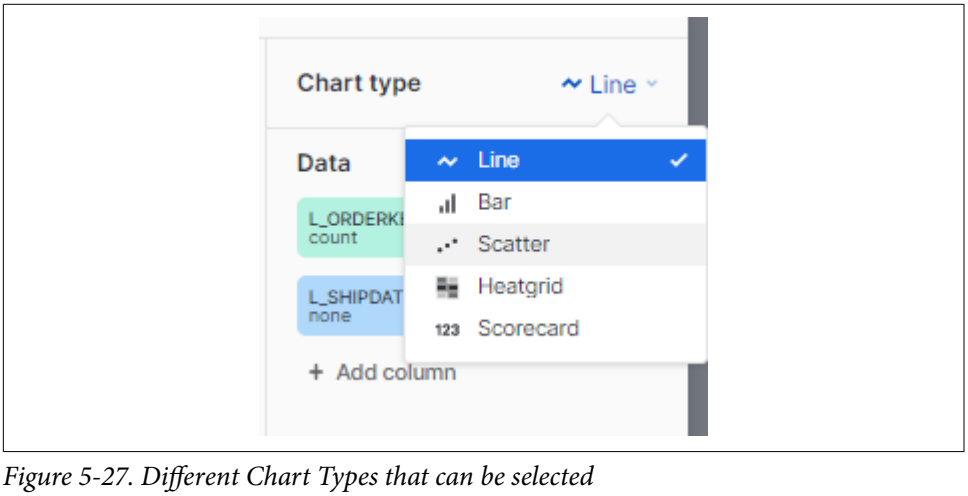



*Figure 5-27. Different Chart Types that can be selected*

At first, you won't see any chart. If you run the query again, though, you'll see the bar chart.

## Aggregating and Bucketing Data

Having the chart results at the daily level and in descending order doesn't provide the visual picture that we think would be helpful. Let's see if we can make some improvements.

Click on the SHIPDATE button to the right (Figure 5-28). Change the Bucketing from None to Month or Quarter, or whatever you think would be best. Try selecting Month and changing the direction to Ascending so that the time goes from left to right. Additionally, take time to label the X and Y axis.

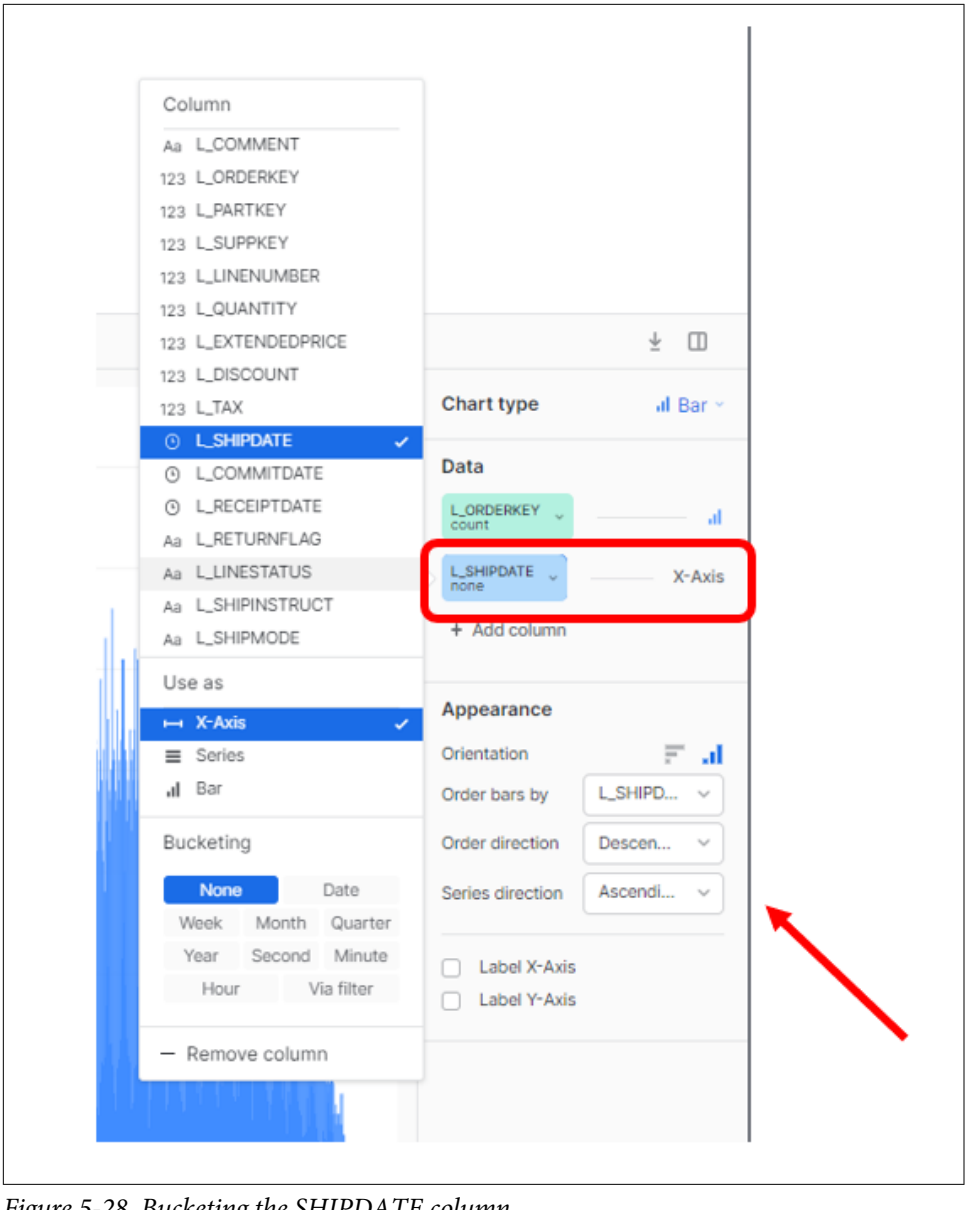



*Figure 5-28. Bucketing the SHIPDATE column*

The changes I made give me a more appealing visualization that I can gain some insights from (Figure 5-29).

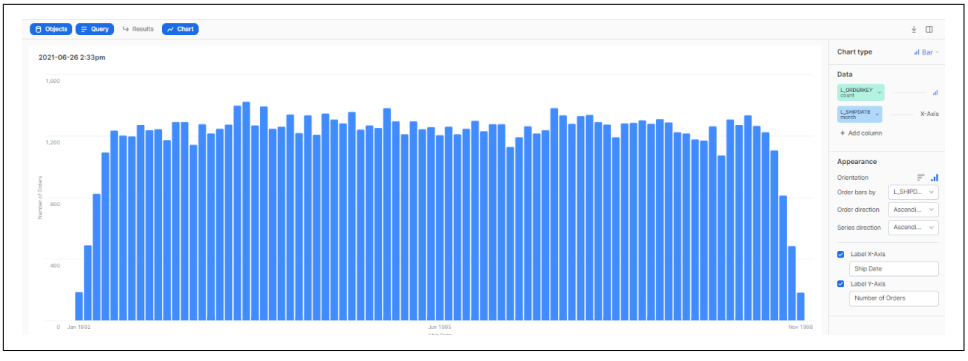



*Figure 5-29. Visualization of data after bucketing SHIPDATE*

Note that if you hover your cursor over the top of any of the bars, you'll see the month and year as well as the number of orders for that particular month.

In the top left corner, you'll see "Return to Chapter 11", with Chapter 11 being the name of your dashboard (Figure 5-30).

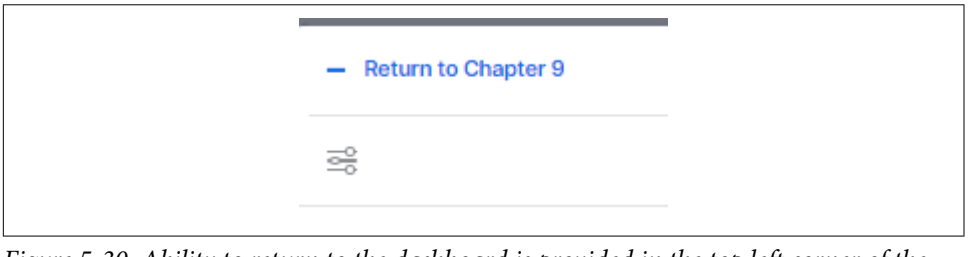



*Figure 5-30. Ability to return to the dashboard is provided in the top left corner of the screen*

To create a new worksheet, click on the + symbol in the top left corner then "New Tile from Worksheet" at the bottom (Figure 5-31).

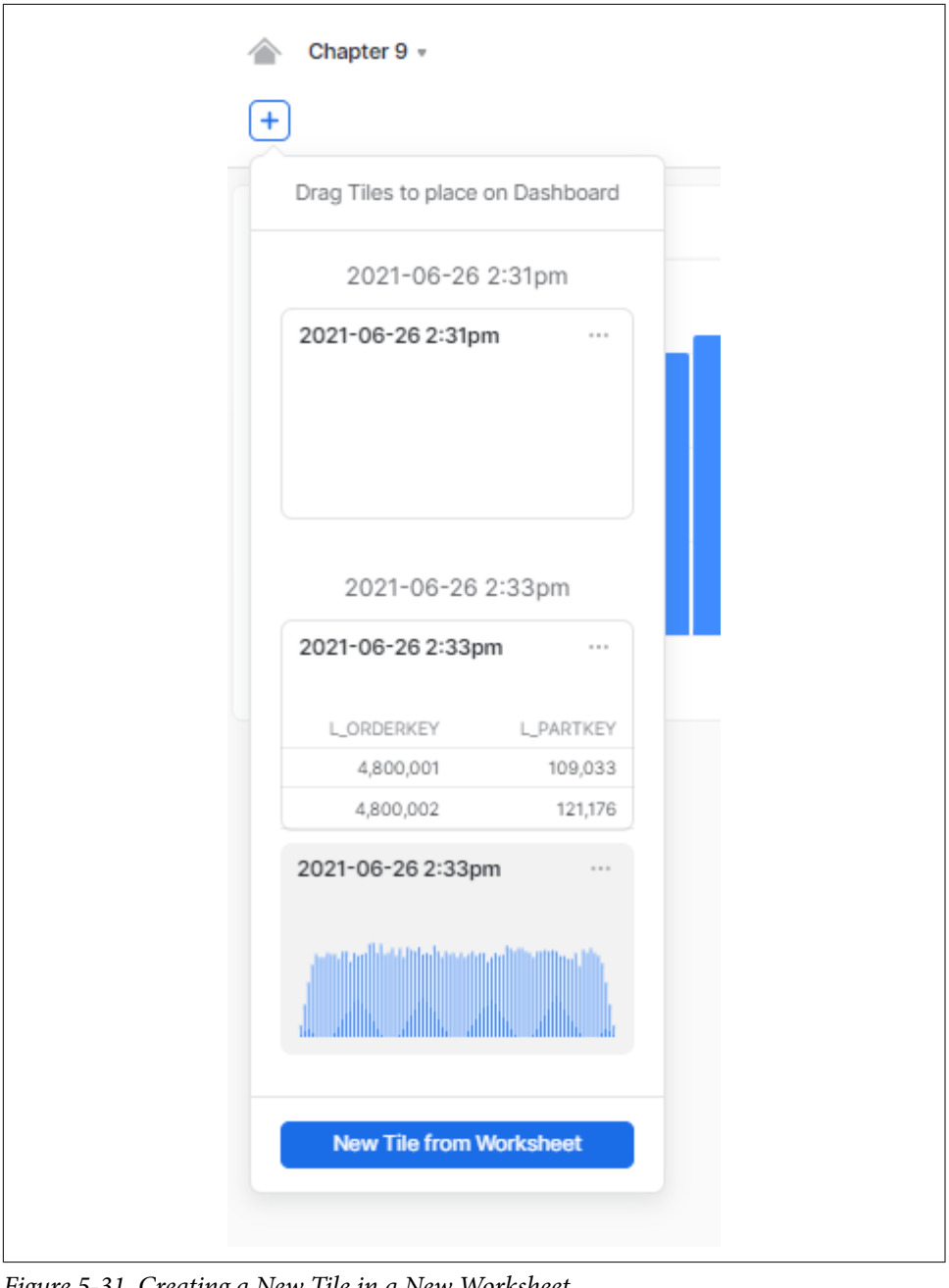



*Figure 5-31. Creating a New Tile in a New Worksheet*

## Editing and Deleting Tiles

Even when placed on the dashboard, individual tiles can be edited. In the top right corner of the chart (Figure 5-32) click on the ellipsis and select from the options. Of course, you can edit the chart by editing the underlying query and one handy feature is that you can duplicate a tile. Duplicating a tile duplicates the underlying worksheet and queries.

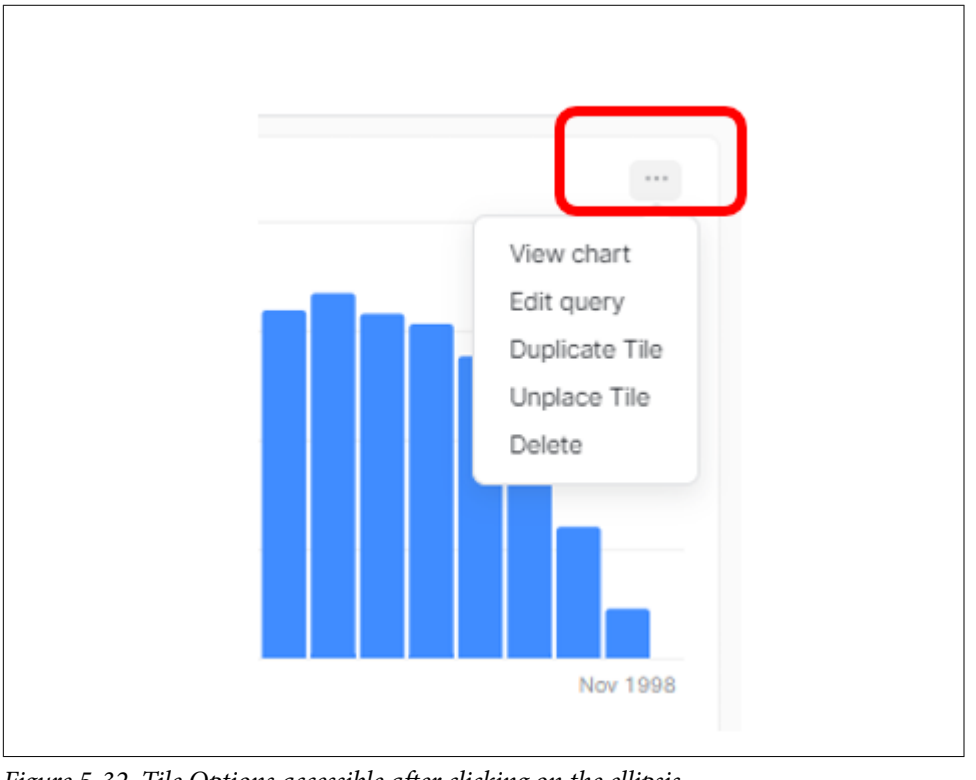



*Figure 5-32. Tile Options accessible after clicking on the ellipsis*

Deleting a tile from a dashboard also permanently deletes the underlying worksheet. You'll not be able to retrieve the tile or worksheet after you perform a delete action.

Deleting a tile is not recommended, unless you are certain that you will not need the worksheet upon which the chart is built. One alternative to deleting a tile is to simply "Unplace Tile" so that it still exists but is not viewable on the dashboard.

# Collaboration

The goal of sharing work product and collaborating is so that the group benefits from the work of individuals without each person or business unit having to recreate the wheel. It also provides the opportunity for more innovation and improvements since everyone can contribute to the knowledge base and move it forward faster.

## Sharing Your Query Results

To share the results of any query, simply click on the down arrow to download a csv file of the query results. The results can then be shared with others (Figure 5-33). You'll notice that the files are saved with the date and timestamp.

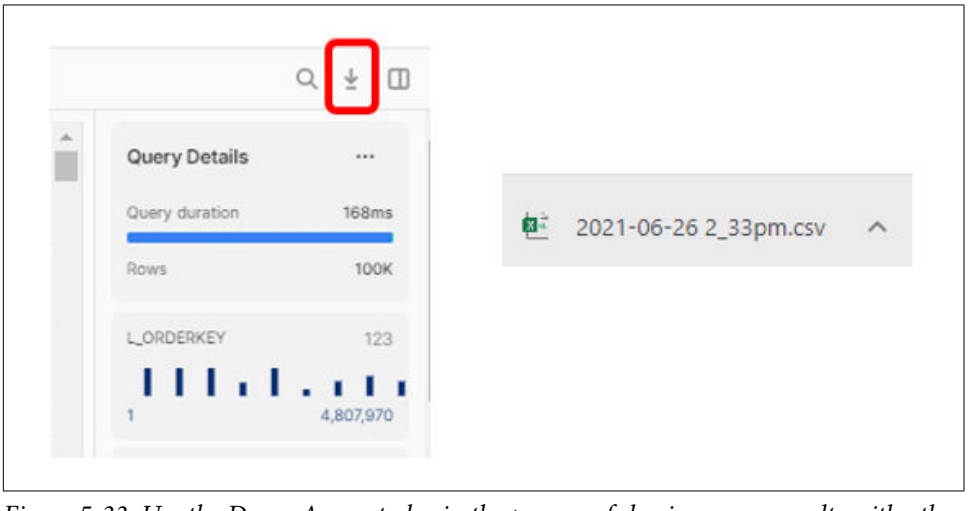



*Figure 5-33. Use the Down Arrow to begin the process of sharing query results with others*

## Using a Private Link to Collaborate on Dashboards

One of the most important Snowsight features is the ability for individuals to collaborate on a dashboard. It's easy to do. In the top left corner, there is a "Share" button (Figure 5-34).

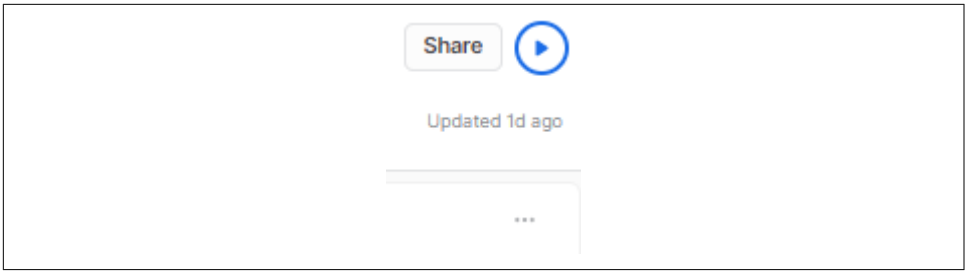



*Figure 5-34. Share button allows for sharing with others for dashboard collaboration*

After you click on the Share button, there is an option to invite users or to let everyone with a link have access to the dashboard. You can authorize a few different privileges for people with the dashboard link, including the ability to only view the results or to run the dashboard which gives them the ability to refresh for the latest results (Figure 5-35).

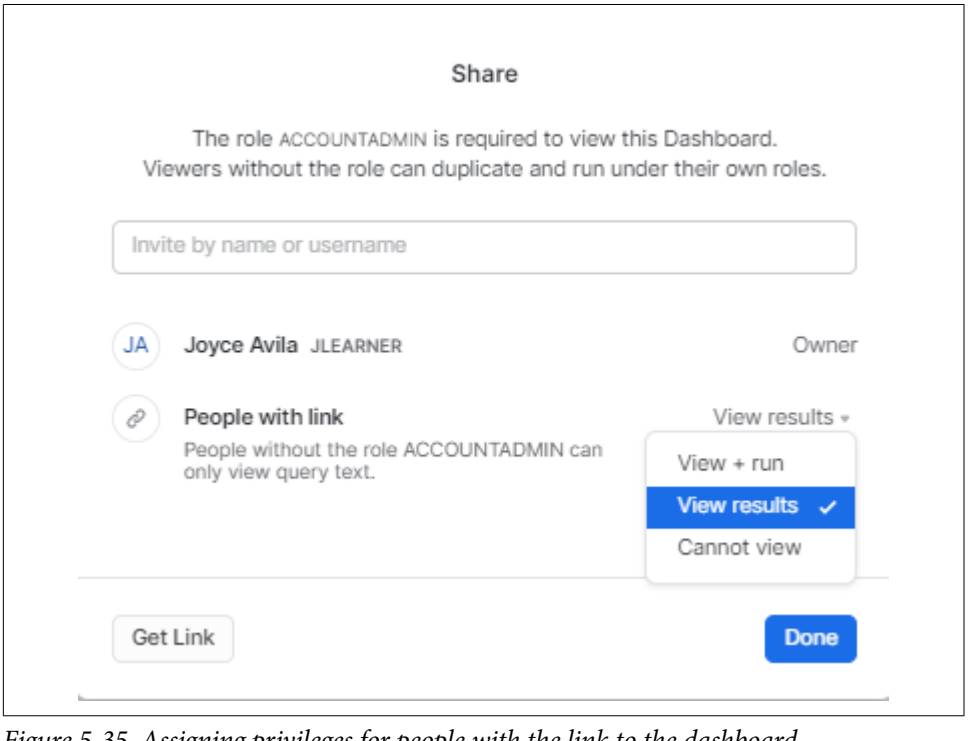



*Figure 5-35. Assigning privileges for people with the link to the dashboard*

A user can filter the results and chart the data to create a dashboard and share it with a colleague within a few minutes without ever having to leave Snowflake and with only using SQL.

## Exercises to Test Your Knowledge

The following exercises are based on the coverage in this chapter.

1. What are the different ways you can instruct Snowflake to return a subset of rows via sampling technique?
2. To use the preview option, do you write a SQL query? How many rows are returned when you use the preview option?
3. When you re-run a sampling query, are the same rows returned the second time as were returned the first time?
4. Is an active warehouse required to run a sampling query? Is an active warehouse required to preview the data?
5. What does "Format SQL" do? Specifically, does "Format SQL" correct your spelling for commands or table names?
6. What happens when you delete a tile from a dashboard?
7. What are some of the use cases for using Snowsight visualizations?
8. What is an alternative to deleting a tile from the dashboard?
9. How many charts can you create from one worksheet?
10. Does Snowflake allow for visualization from internal data sources, external data sources, or both?

Solutions to these exercises are available in Appendix A.

## About the Author

**Joyce Kay Avila** has more than 25 years as a business and technology leader. She is a Texas Certified Public Accountant and currently holds one Amazon Web Services certification and one Snowflake certification. She also holds twelve Salesforce certifications, including the Tableau CRM and Einstein Discovery certification along with several Salesforce Architect-level certifications.

Joyce works as the Snowflake Practice Manager at SpringML, a Snowflake partner who helps organizations unlock the power of data-driven insights using Snowflake's unique cloud data platform. Previously, Joyce earned bachelor's degrees in Computer Science and in Accounting Business Administration, a Master's degree of Business Administration, and completed her PhD coursework in Accounting Information Systems.

In support of the Salesforce and Snowflake communities, Joyce produces a running series of how-to videos on her YouTube channel. In 2022, she was selected as one of 48 Snowflake Data Superheroes worldwide.