JPA Persistence Guide (v5.0)
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We saw in JPA Mapping Guide how to map classes for persistence with the JPA API. In this guide we will describe the JPA API itself, showing how to persist, update and delete objects from persistence.

You should familiarise yourself with the JPA 2.1 Javadoocs.
**EntityManagerFactory**

Any JPA-enabled application will require at least one `EntityManagerFactory` (EMF). Typically applications create one per datastore being utilised. An `EntityManagerFactory` provides access to `EntityManager(s)` which allow objects to be persisted, and retrieved. The `EntityManagerFactory` can be configured to provide particular behaviour.

- An `EntityManagerFactory` is designed to be thread-safe. An `EntityManager` is not.
- An `EntityManagerFactory` is expensive to create so you should create one per datastore for your application and retain it for as long as it is needed. Always close your `EntityManagerFactory` after you have finished with it.

### Create an EMF in JavaSE

The simplest way of creating an `EntityManagerFactory` in a JavaSE environment is as follows:

```java
import javax.persistence.EntityManagerFactory;
import javax.persistence.Persistence;
...
EntityManagerFactory emf = Persistence.createEntityManagerFactory("myPU");
```

Here we provide the name of the `persistence-unit` which defines the datastore, properties, classes, meta-data etc to be used. An alternative is to specify the properties to use along with the `persistence-unit` name; in that case the passed properties will override any that are specified for the persistence unit itself.

```java
EntityManagerFactory emf = Persistence.createEntityManagerFactory("myPU", overridingProps);
```

### Create an EMF in JavaEE

If you want an `application-managed` EMF then you create it by injection like this, providing the name of the required `persistence-unit`:

```java
@PersistenceUnit(unitName="myPU")
EntityManagerFactory emf;
```

If you want a `container-managed` EM then you create it by injection like this, providing the name of the required `persistence-unit`:
Persistence Unit

When designing an application you can usually nicely separate your entities into independent groupings that can be treated separately, perhaps within a different DAO object, if using DAOs. JPA introduces the idea of a persistence-unit. A persistence-unit provides a convenient way of specifying a set of metadata files, and classes, and jars that contain all classes to be persisted in a grouping. The persistence-unit is named, and the name is used for identifying it. Consequently this name can then be used when defining what classes are to be enhanced, for example.

To define a persistence-unit you first need to add a file persistence.xml to the META-INF/ directory of your application jar. This file will be used to define your persistence-unit(s). Let’s show an example
In this example we have defined 2 persistence-units. The first has the name "OnlineStore" and contains 5 classes (annotated). The second has the name "Accounting" and contains a metadata file called orm.xml in a particular package (which will define the classes being part of that unit). This means that once we have defined this we can reference these persistence-unit(s) in our persistence operations. You can find the XSD for persistence.xml here.

There are several sub-elements of this persistence.xml file worth describing

- **provider** - the JPA persistence provider to be used. The JPA persistence "provider" for DataNucleus is `org.datanucleus.api.jpa.PersistenceProviderImpl`

- **jta-data-source** - JNDI name for JTA connections (make sure you set transaction-type as JTA on the persistence-unit for this) **This is only for RDBMS.**
• **non-jta-data-source** - JNDI name for non-JTA connections. Note that if using a JTA datasource as the primary connection, you ought to provide a **non-jta-data-source** also since any schema generation and/or sequence handling will need to use that **This is only for RDBMS**.

• **shared-cache-mode** - Defines the way the L2 cache will operate. ALL means all entities cached. NONE means no entities will be cached. ENABLE_SELECTIVE means only cache the entities that are specified. DISABLE_SELECTIVE means cache all unless specified. UNSPECIFIED leaves it to DataNucleus.

• **validation-mode** - Defines the validation mode for Bean Validation. AUTO, CALLBACK or NONE.

• **jar-file** - name of a JAR file to scan for annotated classes to include in this persistence-unit.

• **mapping-file** - name of an XML “mapping” file containing persistence information to be included in this persistence-unit.

• **class** - name of an annotated class to include in this persistence-unit

• **properties** - properties defining the persistence factory to be used. Please refer to **EMF Properties Guide** for details

• **exclude-unlisted-classes** - Whether to restrict the unit to just classes specified in the unit itself (including jars and mapping-files)

**Metadata loading using persistence unit**

When you specify an EMF using a **persistence.xml** it will load the metadata for all classes that are specified directly in the persistence unit. If you don’t have the **exclude-unlisted-classes** set to true then it will also do a CLASSPATH scan to try to find any other **annotated** classes that are part of that persistence unit. To set the CLASSPATH scanner to a custom version use the persistence property **datanucleus.metadata.scanner** and set it to the class name of the scanner class.

**Specifying the datastore properties**

With a persistence-unit you have 2 ways of specifying the datastore to use

• **Specify the connection URL/driverName/username/password** and it will internally create a DataSource for this URL (or equivalent for non-RDBMS). This is achieved by specifying **javax.persistence.jdbc.url**, **javax.persistence.jdbc.driver**, **javax.persistence.jdbc.user**, and **javax.persistence.jdbc.password** properties. This optionally includes connection pooling dependent on datastore.

• **Specify the JNDI name of the connectionFactory** (only for RDBMS). This is achieved by specifying **javax.persistence.jtaDataSource**, and **javax.persistence.nonJtaDataSource** (for secondary operations) or by specifying the element(s) **jta-data-source/non-jta-data-source**

**Restricting to specific classes**

If you want to just have specific classes in the **persistence-unit** you can specify them using the **class** element, and then add **exclude-unlisted-classes**, like this
If you don't include the `exclude-unlisted-classes` then DataNucleus will search for annotated classes starting at the root of the `persistence-unit` (the root directory in the CLASSPATH that contains the "META-INF/persistence.xml" file).

**Dynamically generated Persistence-Unit**

DataNucleus allows an extension to JPA to dynamically create persistence-units at runtime. Use the following code sample as a guide. Obviously any classes defined in the persistence-unit need to have been enhanced.

```java
import org.datanucleus.metadata.PersistenceUnitMetaData;
import org.datanucleus.api.jpa.JPAEntityManagerFactory;

PersistenceUnitMetaData pumd = new PersistenceUnitMetaData("dynamic-unit", "RESOURCE_LOCAL", null);
pumd.addClassNames("org.datanucleus.test.A");
pumd.setExcludeUnlistedClasses();
pumd.addProperty("javax.persistence.jdbc.url", "jdbc:h2:mem:nucleus");
pumd.addProperty("javax.persistence.jdbc.driver", "org.h2.Driver");
pumd.addProperty("javax.persistence.jdbc.user", "sa");
pumd.addProperty("javax.persistence.jdbc.password", "");
pumd.addProperty("datanucleus.schema.autoCreateAll", "true");

EntityManagerFactory emf = new JPAEntityManagerFactory(pumd, null);
```

It should be noted that if you call `pumd.toString();` then this returns the text that would have been found in a `persistence.xml` file.

**EntityManagerFactory Properties**

An EntityManagerFactory is very configurable, and DataNucleus provides many properties to tailor its behaviour to your persistence needs.

**Standard JPA Properties**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>javax.persistence.provider</td>
<td>Class name of the provider to use. DataNucleus has a provider name of <code>org.datanucleus.api.jpa.PersistenceProviderImpl</code>. If you only have 1 persistence provider in the CLASSPATH then this doesn’t need specifying.</td>
</tr>
<tr>
<td>javax.persistence.transactionType</td>
<td>Type of transactions to use. In Java SE the default is RESOURCE_LOCAL. In Java EE the default is JTA. Note that if using a JTA datasource as the primary connection, you ought to provide a <code>non-jta-data-source</code> also since any schema generation and/or sequence handling will need to use that.</td>
</tr>
<tr>
<td>javax.persistence.jtaDataSource</td>
<td>JNDI name of a (transactional) JTA data source. Note that if using a JTA datasource as the primary connection, you ought to provide a <code>non-jta-data-source</code> also since any schema generation and/or sequence handling will need to use that.</td>
</tr>
<tr>
<td>javax.persistence.nonJtaDataSource</td>
<td>JNDI name of a (non-transactional) data source.</td>
</tr>
<tr>
<td>javax.persistence.jdbc.url</td>
<td>URL specifying the datastore to use for persistence. Note that this will define the <code>type of datastore</code> as well as the datastore itself. Please refer to the datasources guides for the URL appropriate for the type of datastore you're using.</td>
</tr>
<tr>
<td>javax.persistence.jdbc.driver</td>
<td>The name of the (JDBC) driver to use for the DB (for RDBMS only).</td>
</tr>
<tr>
<td>javax.persistence.jdbc.user</td>
<td>Username to use for connecting to the DB</td>
</tr>
<tr>
<td>javax.persistence.jdbc.password</td>
<td>Password to use for connecting to the DB</td>
</tr>
<tr>
<td>javax.persistence.query.timeout</td>
<td>Timeout for queries (global)</td>
</tr>
<tr>
<td>javax.persistence.sharedCache.mode</td>
<td>The mode of operation of the L2 cache, deciding which entities are cached. The default (UNSPECIFIED) is the same as DISABLE_SELECTIVE. See also Cache docs. <code>NONE, ALL, ENABLE_SELECTIVE, DISABLE_SELECTIVE, UNSPECIFIED</code></td>
</tr>
<tr>
<td>javax.persistence.validation.mode</td>
<td>Determines whether the automatic lifecycle event validation is in effect. <code>auto, callback, none</code></td>
</tr>
<tr>
<td>javax.persistence.validation.group.pre-persist</td>
<td>The classes to validation on pre-persist callback</td>
</tr>
<tr>
<td>javax.persistence.validation.group.pre-update</td>
<td>The classes to validation on pre-update callback</td>
</tr>
<tr>
<td>javax.persistence.validation.group.pre-remove</td>
<td>The classes to validation on pre-remove callback</td>
</tr>
<tr>
<td>javax.persistence.validation.factory</td>
<td>The validation factory to use in validation</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.database.action</td>
<td>Whether to perform any schema generation to the database at startup. Will process the schema for all classes that have metadata loaded at startup (i.e the classes specified in a persistence-unit). {create, drop, drop-and-create, none}</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.scripts.action</td>
<td>Whether to perform any schema generation into scripts at startup. Will process the schema for all classes that have metadata loaded at startup (i.e the classes specified in a persistence-unit). {create, drop, drop-and-create, none}</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.scripts.create-target</td>
<td>Name of the script file to write to if doing a &quot;create&quot; with the target as &quot;scripts&quot; {datanucleus-schema-create.ddl, {filename}}</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.scripts.drop-target</td>
<td>Name of the script file to write to if doing a &quot;drop&quot; with the target as &quot;scripts&quot; {datanucleus-schema-drop.ddl, {filename}}</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.create-script-source</td>
<td>Name of a script file to run to create tables. Can be absolute filename, or URL string {filename}</td>
</tr>
<tr>
<td>javax.persistence.schema-generation.drop-script-source</td>
<td>Name of a script file to run to drop tables. Can be absolute filename, or URL string {filename}</td>
</tr>
<tr>
<td>javax.persistence.sql-load-script-source</td>
<td>Name of a script file to run to load data into the schema. Can be absolute filename, or URL string {filename}</td>
</tr>
</tbody>
</table>

**DataNucleus Datastore Properties**

DataNucleus provides the following properties for configuring the datastore used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.ConnectionURL</td>
<td>URL specifying the datastore to use for persistence. Note that this will define the type of datastore as well as the datastore itself. Please refer to the datastores guides for the URL appropriate for the type of datastore you're using.</td>
</tr>
<tr>
<td>datanucleus.ConnectionUserName</td>
<td>Username to use for connecting to the DB</td>
</tr>
<tr>
<td>datanucleus.ConnectionPassword</td>
<td>Password to use for connecting to the DB. See datanucleus.ConnectionPasswordDecrypter for a way of providing an encrypted password here</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.ConnectionDriverName</td>
<td>The name of the (JDBC) driver to use for the DB (for RDBMS only).</td>
</tr>
<tr>
<td>datanucleus.ConnectionFactory</td>
<td>Instance of a connection factory for transactional connections. This is an alternative to <code>datanucleus.ConnectionURL</code>. Only for RDBMS, and it must be an instance of javax.sql.DataSource. See Data Sources.</td>
</tr>
<tr>
<td>datanucleus.ConnectionFactory2</td>
<td>Instance of a connection factory for nontransactional connections. This is an alternative to <code>datanucleus.ConnectionURL</code>. Only for RDBMS, and it must be an instance of javax.sql.DataSource. See Data Sources.</td>
</tr>
<tr>
<td>datanucleus.ConnectionFactoryName</td>
<td>The JNDI name for a connection factory for transactional connections. Only for RDBMS, and it must be a JNDI name that points to a javax.sql.DataSource object. See Data Sources.</td>
</tr>
<tr>
<td>datanucleus.ConnectionFactory2Name</td>
<td>The JNDI name for a connection factory for nontransactional connections. Only for RDBMS, and it must be a JNDI name that points to a javax.sql.DataSource object. See Data Sources.</td>
</tr>
<tr>
<td>datanucleus.PasswordDecrypter</td>
<td>Name of a class that implements org.datanucleus.store.ConnectionEncryptionProvider and should only be specified if the password is encrypted in the persistence properties</td>
</tr>
</tbody>
</table>

**DataNucleus Persistence Properties**

DataNucleus provides the following properties for configuring general persistence handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.IgnoreCache</td>
<td>Whether to ignore the cache for queries. If the user sets this to true then the query will evaluate in the datastore, but the instances returned will be formed from the datastore; this means that if an instance has been modified and its datastore values match the query then the instance returned will not be the currently cached (updated) instance, instead an instance formed using the datastore values. {true, false}</td>
</tr>
<tr>
<td>datanucleus.Multithreaded</td>
<td>Whether to try run the EntityManager as multithreaded. Note that this is only a hint to try to allow thread-safe operations on the EM. Users are always advised to run an EM as single threaded, since some operations are not currently locked and so could cause issues multi-threaded. {true, false}</td>
</tr>
<tr>
<td>datanucleus.Optimistic</td>
<td>Whether to use optimistic transactions (Optimistic locking). {true, false}</td>
</tr>
<tr>
<td>datanucleus.RetainValues</td>
<td>Whether to suppress the clearing of values from persistent instances on transaction completion. {true, false}</td>
</tr>
<tr>
<td>datanucleus.RestoreValues</td>
<td>Whether persistent object have transactional field values restored when transaction rollback occurs. {true, false}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>datanucleus.mapping.Catalog</td>
<td>Name of the catalog to use by default for all classes persisted using this EMF. This can be overridden in the MetaData where required, and is optional. DataNucleus will prefix all table names with this catalog name if the RDBMS supports specification of catalog names in DDL. <strong>RDBMS only</strong></td>
</tr>
<tr>
<td>datanucleus.mapping.Schema</td>
<td>Name of the schema to use by default for all classes persisted using this EMF. This can be overridden in the MetaData where required, and is optional. DataNucleus will prefix all table names with this schema name if the RDBMS supports specification of schema names in DDL. <strong>RDBMS only</strong></td>
</tr>
<tr>
<td>datanucleus.tenantId</td>
<td>String id to use as a discriminator on all persistable class tables to restrict data for the tenant using this application instance (aka multi-tenancy via discriminator). <strong>RDBMS, MongoDB, HBase, Neo4j, Cassandra only</strong></td>
</tr>
<tr>
<td>datanucleus.tenantProvider</td>
<td>Instance of a class that implements org.datanucleus.store.schema.MultiTenancyProvider which will return the tenant name to use for each call. <strong>RDBMS, MongoDB, HBase, Neo4j, Cassandra only</strong></td>
</tr>
<tr>
<td>datanucleus.DetachAllOnCommit</td>
<td>Allows the user to select that when a transaction is committed all objects enlisted in that transaction will be automatically detached. {true, false}</td>
</tr>
<tr>
<td>datanucleus.detachAllOnRollback</td>
<td>Allows the user to select that when a transaction is rolled back all objects enlisted in that transaction will be automatically detached. {true, false}</td>
</tr>
<tr>
<td>datanucleus.CopyOnAttach</td>
<td>Whether, when attaching a detached object, we create an attached copy or simply migrate the detached object to attached state {true, false}</td>
</tr>
<tr>
<td>datanucleus.allowAttachOfTransient</td>
<td>When you call EM.merge with a transient object (with PK fields set), if you enable this feature then it will first check for existence of an object in the datastore with the same identity and, if present, will merge into that object (rather than just trying to persist a new object). {true, false}</td>
</tr>
<tr>
<td>datanucleus.attachSameDatastore</td>
<td>When attaching an object DataNucleus by default assumes that you’re attaching to the same datastore as you detached from. DataNucleus does though allow you to attach to a different datastore (for things like replication). Set this to false if you want to attach to a different datastore to what you detached from. This property is also useful if you are attaching and want it to check for existence of the object in the datastore before attaching, and create it if not present (true assumes that the object exists). {true, false}</td>
</tr>
<tr>
<td>datanucleus.detachAsWrapped</td>
<td>When detaching, any mutable second class objects (Collections, Maps, Dates etc) are typically detached as the basic form (so you can use them on client-side of your application). This property allows you to select to detach as wrapped objects. It only works with &quot;detachAllOnCommit&quot; situations (not with detachCopy) currently {true, false}</td>
</tr>
<tr>
<td>datanucleus.DetachOnClose</td>
<td>This allows the user to specify whether, when an EM is closed, that all objects in the L1 cache are automatically detached. <strong>Users are recommended to use the datanucleus.DetachAllOnCommit wherever possible.</strong> This will not work in JCA mode. {true, false}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.detachmen</td>
<td>When detaching you can control what happens to loaded/unloaded fields of the FetchPlan. The default is to load any unloaded fields of the current FetchPlan before detaching. You can also unload any loaded fields that are not in the current FetchPlan (so you only get the fields you require) as well as a combination of both options (load-fields, unload-fields)</td>
</tr>
<tr>
<td>tFields</td>
<td></td>
</tr>
<tr>
<td>datanucleus.maxFetchDep</td>
<td>Specifies the default maximum fetch depth to use for fetching operations. The JPA spec doesn’t provide fetch group control, just a &quot;default fetch group&quot; type concept, consequently the default there is -1 currently. {-1, 1, positive integer}</td>
</tr>
<tr>
<td>tDepth</td>
<td></td>
</tr>
<tr>
<td>datanucleus.detachedSt</td>
<td>Allows control over which mechanism to use to determine the fields to be detached. By default DataNucleus uses the defined &quot;fetch-groups&quot;. Obviously JPA doesn’t have that (although it is an option with DataNucleus), so we also allow loaded which will detach just the currently loaded fields, and all which will detach all fields of the object (be careful with this option since it, when used with maxFetchDepth of -1 will detach a whole object graph!) {fetch-groups, all, loaded}</td>
</tr>
<tr>
<td>atate</td>
<td></td>
</tr>
<tr>
<td>datanucleus.ServerTime</td>
<td>Id of the TimeZone under which the datastore server is running. If this is not specified or is set to null it is assumed that the datastore server is running in the same timezone as the JVM under which DataNucleus is running.</td>
</tr>
<tr>
<td>ZoneID</td>
<td></td>
</tr>
<tr>
<td>datanucleus.Persistenc</td>
<td>Used when we have specified the persistence-unit name for a EMF and where we want the datastore &quot;tables&quot; for all classes of that persistence-unit loading up into the StoreManager. Defaults to false since some databases are slow so such an operation would slow down the startup process. {true, false}</td>
</tr>
<tr>
<td>eUnitLoadClasses</td>
<td></td>
</tr>
<tr>
<td>datanucleus.persistence</td>
<td>URL name of the persistence.xml file that should be used instead of using META-INF/persistence.xml.</td>
</tr>
<tr>
<td>XmlFilename</td>
<td></td>
</tr>
<tr>
<td>datanucleus.datastoreR</td>
<td>The timeout to apply to all reads (millisecs) (query or find operations). Only applies if the underlying datastore supports it (0, positive value)</td>
</tr>
<tr>
<td>eadTimeout</td>
<td></td>
</tr>
<tr>
<td>datanucleus.datastoreW</td>
<td>The timeout to apply to all writes (millisecs). (persist operations). Only applies if the underlying datastore supports it (0, positive value)</td>
</tr>
<tr>
<td>riteTimeout</td>
<td></td>
</tr>
<tr>
<td>datanucleus.singletonE</td>
<td>Whether to only allow a singleton EMF for persistence-unit. If a subsequent request is made for an EMF with a name that already exists then a warning will be logged and the original EMF returned. {true, false}</td>
</tr>
<tr>
<td>MFForName</td>
<td></td>
</tr>
<tr>
<td>datanucleus.storeMana</td>
<td>Type of the StoreManager to use for this EMF. This has typical values of &quot;rdbms&quot;, &quot;mongodb&quot;. If it isn’t specified then it falls back to trying to find the StoreManager from the connection URL. The associated DataNucleus plugin has to be in the CLASSPATH when selecting this. When using data sources (as usually done in a JavaEE container), DataNucleus cannot find out the correct type automatically and this option must be set.</td>
</tr>
<tr>
<td>gerType</td>
<td></td>
</tr>
<tr>
<td>datanucleus.jmxType</td>
<td>Which JMX server to use when hooking into JMX. Please refer to the Monitoring Guide {default, mx4j}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.deletionPolicy</td>
<td>Allows the user to decide the policy when deleting objects. The default is &quot;JDO2&quot; which firstly checks if the field is dependent and if so deletes dependents, and then for others will null any foreign keys out. The problem with this option is that it takes no account of whether the user has also defined foreign-key metadata, so we provide a &quot;DataNucleus&quot; mode that does the dependent field part first and then if a FK element is defined will leave it to the FK in the datastore to perform any actions, and otherwise does the nulling. {JDO2, DataNucleus}</td>
</tr>
<tr>
<td>datanucleus.identityStringTranslatorType</td>
<td>You can allow identities input to \em.find(id) be translated into valid ids if there is a suitable translator. See Identity String Translator Extension</td>
</tr>
<tr>
<td>datanucleus.identityKeyTranslatorType</td>
<td>You can allow identities input to \em.find(cls, key) be translated into valid ids if there is a suitable key translator. See Identity Key Translator Extension</td>
</tr>
<tr>
<td>datanucleus.datastoreIdentityType</td>
<td>Which &quot;datastore-identity&quot; class plugin to use to represent datastore identities. See Datastore Identity extension for details. {datanucleus, kodo, xcalia, ...}</td>
</tr>
<tr>
<td>datanucleus.executionContext.maxIdle</td>
<td>Specifies the maximum number of ExecutionContext objects that are pooled ready for use {20}</td>
</tr>
<tr>
<td>datanucleus.executionContext.reaperThread</td>
<td>Whether to start a reaper thread that continually monitors the pool of ExecutionContext objects and frees them off after they have surpassed their expiration period {true, false}</td>
</tr>
<tr>
<td>datanucleus.executionContext.closeActiveTxAction</td>
<td>Defines the action if an EM is closed and there is an active transaction present. {rollback, exception}</td>
</tr>
<tr>
<td>datanucleus.objectProvider.className</td>
<td>Class name for the ObjectProvider to use when managing object state. The default for RDBMS is ReferentialStateManagerImpl, and is StateManagerImpl for all other datastores.</td>
</tr>
<tr>
<td>datanucleus.manageRelationships</td>
<td>This allows the user control over whether DataNucleus will try to manage bidirectional relations, correcting the input objects so that all relations are consistent. This process runs when flush()/commit() is called. {true, false}</td>
</tr>
<tr>
<td>datanucleus.manageRelationshipsChecks</td>
<td>This allows the user control over whether DataNucleus will make consistency checks on bidirectional relations. If &quot;datanucleus.managedRelationships&quot; is not selected then no checks are performed. If a consistency check fails at flush()/commit() then an exception is thrown. {true, false}</td>
</tr>
<tr>
<td>datanucleus.persistanceByReachabilityAtCommit</td>
<td>Whether to run the &quot;persistence-by-reachability&quot; algorithm at commit() time. This means that objects that were reachable at a call to makePersistent() but that are no longer persistent will be removed from persistence. Turn this off for performance. {true, false}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.classLoaderResolverName</td>
<td>Name of a ClassLoaderResolver to use in class loading. This property allows the user to override the default with their own class better suited to their own loading requirements. <strong>{datanucleus, (name of class-loader-resolver plugin)}</strong></td>
</tr>
<tr>
<td>datanucleus.primaryClassLoader</td>
<td>Sets a primary classloader for situations where a primary classloader is not accessible. This ClassLoader is used when the class is not found in the default ClassLoader search path. As example, when the database driver is loaded by a different ClassLoader not in the ClassLoader search path for PA specifications.</td>
</tr>
<tr>
<td>datanucleus.plugin.pluginRegistryClassName</td>
<td>Name of a class that acts as registry for plug-ins. This defaults to <strong>org.datanucleus.plugin.NonManagedPluginRegistry</strong> (for when not using OSGi). If you are within an OSGi environment you can set this to <strong>org.datanucleus.plugin.OSGiPluginRegistry</strong></td>
</tr>
<tr>
<td>datanucleus.plugin.pluginRegistryBundleCheck</td>
<td>Defines what happens when plugin bundles are found and are duplicated <strong>{exception, log, none}</strong></td>
</tr>
<tr>
<td>datanucleus.plugin.allowUserBundles</td>
<td>Defines whether user-provided bundles providing DataNucleus extensions will be registered. This is only respected if used in a non-Eclipse OSGi environment. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.plugin.validatePlugins</td>
<td>Defines whether a validation step should be performed checking for plugin dependencies etc. This is only respected if used in a non-Eclipse OSGi environment. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.findObject.validateWhenCached</td>
<td>When a user calls em.find this turns off of validation when an object is found in the (L2) cache. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.findObject.typeConversion</td>
<td>When calling em.find(Class, Object) the second argument really ought to be the exact type of the primary-key field. This property enables conversion of basic numeric types (Long, Integer, Short) to the appropriate numeric type (if the PK is a numeric type). Set this to <strong>false</strong> if you want strict JPA compliance. <strong>{true, false}</strong></td>
</tr>
</tbody>
</table>

### DataNucleus Schema Properties

DataNucleus provides the following properties for configuring schema handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.schema.autoCreateAll</td>
<td>Whether to automatically generate any schema, tables, columns, constraints that don’t exist. Please refer to the Schema Guide for more details. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>datanucleus.schema.au toCreateDatabase</td>
<td>Whether to automatically generate any database (catalog/schema) that doesn't exist. This depends very much on whether the datastore in question supports this operation. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.au toCreateTables</td>
<td>Whether to automatically generate any tables that don’t exist. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.au toCreateColumns</td>
<td>Whether to automatically generate any columns that don’t exist. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.au toCreateConstraints</td>
<td>Whether to automatically generate any constraints that don’t exist. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.autoCreateWarnOnError</td>
<td>Whether to only log a warning when errors occur during the auto-creation/validation process. Please use with care since if the schema is incorrect errors will likely come up later and this will postpone those error checks til later, when it may be too late!! {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.val idateAll</td>
<td>Alias for defining datanucleus.schema.validateTables, datanucleus.schema.validateColumns and datanucleus.schema.validateConstraints as all true. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.val idateTables</td>
<td>Whether to validate tables against the persistence definition. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.val idateColumns</td>
<td>Whether to validate columns against the persistence definition. This refers to the column detail structure and NOT to whether the column exists or not. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.schema.val idateConstraints</td>
<td>Whether to validate table constraints against the persistence definition. Please refer to the Schema Guide for more details. {true, false}</td>
</tr>
<tr>
<td>datanucleus.readOnlyD atastore</td>
<td>Whether the datastore is read-only or not (fixed in structure and contents) {true, false}</td>
</tr>
<tr>
<td>datanucleus.readOnlyD atastoreAction</td>
<td>What happens when a datastore is read-only and an object is attempted to be persisted. {exception, ignore}</td>
</tr>
<tr>
<td>datanucleus.generateSc hema.database.mode</td>
<td>Whether to perform any schema generation to the database at startup. Will process the schema for all classes that have metadata loaded at startup (i.e the classes specified in a persistence-unit). {create, drop, drop-and-create, none}</td>
</tr>
<tr>
<td>datanucleus.generateSc hema.scripts.mode</td>
<td>Whether to perform any schema generation into scripts at startup. Will process the schema for all classes that have metadata loaded at startup  (i.e the classes specified in a persistence-unit). {create, drop, drop-and-create, none}</td>
</tr>
<tr>
<td>datanucleus.generateSc hema.scripts.create.tar get</td>
<td>Name of the script file to write to if doing a &quot;create&quot; with the target as &quot;scripts&quot; {datanucleus-schema-create.ddl, {filename}}</td>
</tr>
</tbody>
</table>
### DataNucleus Transaction Properties

DataNucleus provides the following properties for configuring transaction handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.transactionType</td>
<td>Type of transaction to use. If running under JavaSE the default is RESOURCE_LOCAL, and if running under JavaEE the default is JTA. {RESOURCE_LOCAL, JTA}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.transactionIsolation</td>
<td>Select the default transaction isolation level for ALL EntityManagers. Some databases do not support all isolation levels, refer to your database documentation. Please refer to the transaction guide {read-uncommitted, read-committed, repeatable-read, serializable}</td>
</tr>
<tr>
<td>datanucleus.jtaLocator</td>
<td>Selects the locator to use when using JTA transactions so that DataNucleus can find the JTA TransactionManager. If this isn't specified and using JTA transactions DataNucleus will search all available locators which could have a performance impact. See JTA Locator extension. If specifying &quot;custom_jndi&quot; please also specify &quot;datanucleus.jtaJndiLocation&quot; {autodetect, jboss, jonas, jotm, oc4j, orion, resin, sap, sun, weblogic, websphere, custom_jndi, alias of a JTA transaction locator}</td>
</tr>
<tr>
<td>datanucleus.jtaJndiLocation</td>
<td>Name of a JNDI location to find the JTA transaction manager from (when using JTA transactions). This is for the case where you know where it is located. If not used DataNucleus will try certain well-known locations</td>
</tr>
<tr>
<td>datanucleus.nontransactionalRead</td>
<td>Whether to allow nontransactional reads {false, true}</td>
</tr>
<tr>
<td>datanucleus.nontransactionalWrite</td>
<td>Whether to allow nontransactional writes {false, true}</td>
</tr>
<tr>
<td>datanucleus.nontx.atomic</td>
<td>When a user invokes a nontransactional operation they can choose for these changes to go straight to the datastore (atomically) or to wait until either the next transaction commit, or close of the EM. Disable this if you want operations to be processed with the next real transaction. {true, false}</td>
</tr>
<tr>
<td>datanucleus.SerializeRead</td>
<td>With datastore transactions you can apply locking to objects as they are read from the datastore. This setting applies as the default for all EMs obtained. You can also specify this on a per-transaction or per-query basis (which is often better to avoid deadlocks etc) {true, false}</td>
</tr>
<tr>
<td>datanucleus.datastoreTransactionFlushLimit</td>
<td>For use when using pessimistic transactions and is the limit on number of dirty objects before a flush to the datastore will be performed. {1}</td>
</tr>
<tr>
<td>datanucleus.flush.mode</td>
<td>Sets when persistence operations are flushed to the datastore. MANUAL means that operations will be sent only on flush()/commit(). AUTO means that operations will be sent immediately. {MANUAL, AUTO}</td>
</tr>
<tr>
<td>datanucleus.flush.optimised</td>
<td>Whether to use an &quot;optimised&quot; flush process, changing the order of persists for referential integrity (as used by RDBMS typically), or whether to just build a list of deletes, inserts and updates and do them in batches. RDBMS defaults to true, whereas other datastores default to false (due to not having referential integrity, so gaining from batching {true, false}</td>
</tr>
<tr>
<td>datanucleus.connectionPoolingType</td>
<td>This property allows you to utilise a 3rd party software package for enabling connection pooling. When using RDBMS you can select from DBCP, C3P0, Proxool, BoneCP, etc. You must have the 3rd party jars in the CLASSPATH to use these options. Please refer to the Connection Pooling guide for details. {None, dbcp2-built-in, DBCP, DBCP2, C3P0, Proxool, BoneCP, HikariCP, Tomcat, {others}}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>datanucleus.connection.PoolingType.nontx</td>
<td>This property allows you to utilise a 3rd party software package for enabling connection pooling for nontransactional connections using a DataNucleus plugin. If you don't specify this value but do define the above value then that is taken by default. Refer to the above property for more details. {None, dbcp2-builtint, DBCP, DBCP2, C3P0, Proxool, BoneCP, HikariCP, Tomcat, {others}}</td>
</tr>
<tr>
<td>datanucleus.connection.nontx.releaseAfterUse</td>
<td>Applies only to non-transactional connections and refers to whether to re-use (pool) the connection internally for later use. The default behaviour is to close any such non-transactional connection after use. If doing significant non-transactional processing in your application then this may provide performance benefits, but be careful about the number of connections being held open (if one is held open per EM). {true, false}</td>
</tr>
<tr>
<td>datanucleus.connection.singleConnectionPerExecutionContext</td>
<td>With an ExecutionContext (EM) we normally allocate one connection for a transaction and close it after the transaction, then a different connection for nontransactional ops. This flag acts as a hint to the store plugin to obtain and retain a single connection throughout the lifetime of the EM. {true, false}</td>
</tr>
<tr>
<td>datanucleus.connection.resourceType</td>
<td>Resource Type for primary connection {RESOURCE_LOCAL, JTA}</td>
</tr>
<tr>
<td>datanucleus.connection.resourceType2</td>
<td>Resource Type for secondary connection {RESOURCE_LOCAL, JTA}</td>
</tr>
</tbody>
</table>

**DataNucleus Cache Properties**

DataNucleus provides the following properties for configuring cache handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.cache.collections</td>
<td>SCO collections can be used in 2 modes in DataNucleus. You can allow DataNucleus to cache the collections contents, or you can tell DataNucleus to access the datastore for every access of the SCO collection. The default is to use the cached collection. {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.collections.lazy</td>
<td>When using cached collections/maps, the elements(keys/values) can be loaded when the object is initialised, or can be loaded when accessed (lazy loading). The default is to use lazy loading when the field is not in the current fetch group, and to not use lazy loading when the field is in the current fetch group. {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.level1.type</td>
<td>Name of the type of Level 1 cache to use. Defines the backing map. See also L1 Cache docs {soft, weak, strong, {your-plugin-name}}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.type</td>
<td>Name of the type of Level 2 Cache to use. Can be used to interface with external caching products. Use &quot;none&quot; to turn off L2 caching. See also L2 Cache docs {none, soft, weak, coherence, ehcache, ehcacheclassbased, cacheonix, oscache, swarmcache, javax.cache, spymemcached, xmemcached, {your-plugin-name}}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.mode</td>
<td>The mode of operation of the L2 cache, deciding which entities are cached. The default (UNSPECIFIED) is the same as DISABLE_SELECTIVE. See also L2 Cache docs {NONE, ALL, ENABLE_SELECTIVE, DISABLE_SELECTIVE, UNSPECIFIED}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.storeMode</td>
<td>Whether to use the L2 cache for storing values (set to &quot;bypass&quot; to not store within the context of the operation) {use, bypass}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.retrieveMode</td>
<td>Whether to use the L2 cache for retrieving values (set to &quot;bypass&quot; to not retrieve from L2 cache within the context of the operation, i.e go to the datastore) {use, bypass}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.updateMode</td>
<td>When the objects in the L2 cache should be updated. Defaults to updating at commit AND when fields are read from a datastore object {commit-and-datastore-read, commit}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.cacheName</td>
<td>Name of the cache. This is for use with plugins such as the Tangosol cache plugin for accessing the particular cache. Please refer to the L2 Cache docs</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.maxSize</td>
<td>Max size for the L2 cache (supported by weak, soft, coherence, ehcache, ehcacheclassbased, javax.cache) {-1, integer value}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.clearAtClose</td>
<td>Whether the close of the L2 cache (when the EMF closes) should also clear any objects from the underlying cache mechanism. By default it will clear objects out but if the user has configured an external cache product and wants to share objects across multiple EMFs then this can be set to false. {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.batchSize</td>
<td>When objects are added to the L2 cache at commit they are typically batched. This property sets the max size of the batch. {100, integer value}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.timeout</td>
<td>Some caches (Cacheonix, javax.cache) allow specification of an expiration time for objects in the cache. This property is the timeout in milliseconds (will be unset meaning use cache default). {-1, integer value}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.readThrough</td>
<td>With javax.cache L2 caches you can configure the cache to allow read-through {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.writeThrough</td>
<td>With javax.cache L2 caches you can configure the cache to allow write-through {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.storeByValue</td>
<td>With javax.cache L2 caches you can configure the cache to store by value (as opposed to by reference) {true, false}</td>
</tr>
<tr>
<td>datanucleus.cache.level 2.statisticsEnabled</td>
<td>With javax.cache L2 caches you can configure the cache to enable statistics gathering (accessible via JMX) {false, true}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datanucleus.cache.queryCompilation.type</td>
<td>Type of cache to use for caching of generic query compilations {none, soft, weak, strong, javax.cache, {your-plugin-name}}</td>
</tr>
<tr>
<td>datanucleus.cache.queryCompilation.cacheName</td>
<td>Name of cache for generic query compilation. Used by javax.cache variant. {{your-cache-name}, datanucleus-query-compilation}</td>
</tr>
<tr>
<td>datanucleus.cache.queryCompilationDatastore.type</td>
<td>Type of cache to use for caching of datastore query compilations {none, soft, weak, strong, javax.cache, {your-plugin-name}}</td>
</tr>
<tr>
<td>datanucleus.cache.queryCompilationDatastore.cacheName</td>
<td>Name of cache for datastore query compilation. Used by javax.cache variant. {{your-cache-name}, datanucleus-query-compilation-datastore}</td>
</tr>
<tr>
<td>datanucleus.cache.queryResults.type</td>
<td>Type of cache to use for caching query results. {none, soft, weak, strong, javax.cache, spymemcached, xmembcached, cacheonix, {your-plugin-name}}</td>
</tr>
<tr>
<td>datanucleus.cache.queryResults.cacheName</td>
<td>Name of cache for caching the query results. {datanucleus-query, {your-name}}</td>
</tr>
<tr>
<td>datanucleus.cache.queryResults.maxSize</td>
<td>Max size for the query results cache (supported by weak, soft, strong) {-1, integer value}</td>
</tr>
</tbody>
</table>

**DataNucleus Bean Validation Properties**

DataNucleus provides the following properties for configuring bean validation handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.validation.mode</td>
<td>Determines whether the automatic lifecycle event validation is in effect. {auto, callback, none}</td>
</tr>
<tr>
<td>datanucleus.validation.group.pre-persist</td>
<td>The classes to validation on pre-persist callback</td>
</tr>
<tr>
<td>datanucleus.validation.group.pre-update</td>
<td>The classes to validation on pre-update callback</td>
</tr>
<tr>
<td>datanucleus.validation.group.pre-remove</td>
<td>The classes to validation on pre-remove callback</td>
</tr>
<tr>
<td>datanucleus.validation.factory</td>
<td>The validation factory to use in validation</td>
</tr>
</tbody>
</table>

**DataNucleus Value Generation Properties**

19
DataNucleus provides the following properties for configuring value generation handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.valuegeneration.transactionAttribute</td>
<td>Whether to use the EM connection or open a new connection. Only used by value generators that require a connection to the datastore. <strong>{New, UsePM}</strong></td>
</tr>
<tr>
<td>datanucleus.valuegeneration.transactionIsolation</td>
<td>Select the default transaction isolation level for identity generation. Must have <code>datanucleus.valuegeneration.transactionAttribute</code> set to <code>New</code>. Some databases do not support all isolation levels, refer to your database documentation. Please refer to the transaction guide <strong>{read-uncommitted, read-committed, repeatable-read, serializable}</strong></td>
</tr>
</tbody>
</table>

**DataNucleus Metadata Properties**

DataNucleus provides the following properties for configuring metadata handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.metadata.alwaysDetachable</td>
<td>Whether to treat all classes as detachable irrespective of input metadata. See also &quot;alwaysDetachable&quot; enhancer option. <strong>{false, true}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.listener.object</td>
<td>Property specifying a org.datanucleus.metadata.MetaDataListener object that will be registered at startup and will receive notification of all metadata load activity. <strong>{false, true}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.ignoreMetaDataForMissingClasses</td>
<td>Whether to ignore classes where metadata is specified. Default (false) is to throw an exception. <strong>{false, true}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.xml.validate</td>
<td>Whether to validate the MetaData file(s) for XML correctness (against the DTD) when parsing. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.xml.namespaceAware</td>
<td>Whether to allow for XML namespaces in metadata files. The vast majority of sane people should not need this at all, but it's enabled by default to allow for those that do (since v3.2.3) <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.allowXML</td>
<td>Whether to allow XML metadata. Turn this off if not using any, for performance. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.allowAnnotations</td>
<td>Whether to allow annotations metadata. Turn this off if not using any, for performance. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.allowLoadAtRuntime</td>
<td>Whether to allow load of metadata at runtime. This is intended for the situation where you are handling persistence of a persistence-unit and only want the classes explicitly specified in the persistence-unit. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>datanucleus.metadata.autoregistration</td>
<td>Whether to use the bytecode contract auto-registration of metadata. <strong>{true, false}</strong></td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td><code>datanucleus.metadata.defaultNullable</code></td>
<td>Whether the default nullability for the fields should be nullable or non-nullable when no metadata regarding field nullability is specified at field level. The default is nullable i.e. to allow null values (since v5.0.0). <code>{true, false}</code></td>
</tr>
<tr>
<td><code>datanucleus.metadata.scanner</code></td>
<td>Name of a class to use for scanning the classpath for persistent classes when using a <code>persistence.xml</code>. The class must implement the interface <code>org.datanucleus.metadata.MetaDataScanner</code></td>
</tr>
<tr>
<td><code>datanucleus.metadata.useDiscriminatorForSingleTable</code></td>
<td>With JPA the spec implies that all use of &quot;single-table&quot; inheritance will use a discriminator. DataNucleus up to and including 5.0.2 relied on the user defining the discriminator, whereas it now will add one if not supplied. Set this to <code>false</code> to get behaviour as it was ≈ 5.0.2 <code>{true, false}</code></td>
</tr>
</tbody>
</table>

**DataNucleus Query Properties**

DataNucleus provides the following properties for configuring query handling used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>datanucleus.query.flushBeforeExecution</code></td>
<td>This property can enforce a flush to the datastore of any outstanding changes just before executing all queries. If using optimistic transactions any updates are typically held back until flush/commit and so the query would otherwise not take them into account. <code>{true, false}</code></td>
</tr>
<tr>
<td><code>datanucleus.query.jpql.allowRange</code></td>
<td>JPQL queries, by the JPA spec, do not allow specification of the range in the query string. This extension to allow &quot;RANGE x,y&quot; after the ORDER BY clause of JPQL string queries. <code>{false, true}</code></td>
</tr>
<tr>
<td><code>datanucleus.query.checkUnusedParameters</code></td>
<td>Whether to check for unused input parameters and throw an exception if found. The JPA spec requires this check and is a good guide to having misnamed a parameter name in the query for example. <code>{true, false}</code></td>
</tr>
</tbody>
</table>

**DataNucleus Datastore-Specific Properties**

DataNucleus provides the following properties for configuring datastore-specific used by the EntityManagerFactory.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>datanucleus.rdbms.datastoreAdapterClassName</code></td>
<td>This property allows you to supply the class name of the adapter to use for your datastore. The default is not to specify this property and DataNucleus will autodetect the datastore type and use its own internal datastore adapter classes. This allows you to override the default behaviour where there maybe is some issue with the default adapter class. <strong>Applicable for RDBMS only</strong></td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.useLegacyNativeValueStrategy</code></td>
<td>This property changes the process for deciding the value strategy to use when the user has selected &quot;auto&quot; to be like it was with version 3.0 and earlier, so using &quot;increment&quot; and &quot;uuid-hex&quot;. <strong>Applicable for RDBMS only</strong> (true, false)</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.statememtBatchLimit</code></td>
<td>Maximum number of statements that can be batched. The default is 50 and also applies to delete of objects. Please refer to the Statement Batching guide <strong>Applicable for RDBMS only</strong> (integer value (0 = no batching))</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.checkExistTablesOrViews</code></td>
<td>Whether to check if the table/view exists. If false, it disables the automatic generation of tables that don't exist. <strong>Applicable for RDBMS only</strong> (true, false)</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.useDefaultSqlType</code></td>
<td>This property applies for schema generation in terms of setting the default column &quot;sql-type&quot; (when you haven't defined it) and where the JDBC driver has multiple possible &quot;sql-type&quot; for a &quot;jdbc-type&quot;. If the property is set to false, it will take the first provided &quot;sql-type&quot; from the JDBC driver. If the property is set to true, it will take the &quot;sql-type&quot; that matches what the DataNucleus &quot;plugin.xml&quot; implies. <strong>Applicable for RDBMS only</strong>. {true, false}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.initializeColumnInfo</code></td>
<td>Allows control over what column information is initialised when a table is loaded for the first time. By default info for all columns will be loaded. Unfortunately some RDBMS are particularly poor at returning this information so we allow reduced forms to just load the primary key column info, or not to load any. <strong>Applicable for RDBMS only</strong> {ALL, PK, NONE}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.classNameAdditionMaxRetries</code></td>
<td>The maximum number of retries when trying to find a class to persist or when validating a class. <strong>Applicable for RDBMS only</strong> {3, A positive integer}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.constraintCreateMode</code></td>
<td>How to determine the RDBMS constraints to be created. <strong>DataNucleus</strong> will automatically add foreign-keys/indices to handle all relationships, and will utilise the specified MetaData foreign-key information. <strong>JDO2</strong> will only use the information in the MetaData file(s). <strong>Applicable for RDBMS only</strong>. {DataNucleus, JDO2}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.uniqueConstraints.mapInverse</code></td>
<td>Whether to add unique constraints to the element table for a map inverse field. <strong>Applicable for RDBMS only</strong>. {true, false}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.discriminatorPerSubclassTable</code></td>
<td>Property that controls if only the base class where the discriminator is defined will have a discriminator column <strong>Applicable for RDBMS only</strong>. {false, true}</td>
</tr>
<tr>
<td><code>datanucleus.rdbms.stringDefaultLength</code></td>
<td>The default (max) length to use for all strings that don't have their column length defined in MetaData. <strong>Applicable for RDBMS only</strong>. {255, A valid length}</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>datanucleus.rdbms.stringLengthExceededAction</td>
<td>Defines what happens when persisting a String field and its length exceeds the length of the underlying datastore column. The default is to throw an Exception. The other option is to truncate the String to the length of the datastore column. <strong>Applicable for RDBMS only</strong> {EXCEPTION, TRUNCATE}</td>
</tr>
<tr>
<td>datanucleus.rdbms.useColumnDefaultWhenNull</td>
<td>If an object is being persisted and a field (column) is null, the default behaviour is to look whether the column has a &quot;default&quot; value defined in the datastore and pass that in. You can turn this off and instead pass in NULL for the column by setting this property to false. <strong>Applicable for RDBMS only</strong>. {true, false}</td>
</tr>
<tr>
<td>datanucleus.rdbms.persistEmptyStringAsNull</td>
<td>When persisting an empty string, should it be persisted as null in the datastore? This is to allow for datastores such as Oracle that dont differentiate between null and empty string. If it is set to false and the datastore doesnt differentiate then a special character will be saved when storing an empty string (and interpreted when reading in). <strong>Applicable for RDBMS only</strong> {true, false}</td>
</tr>
<tr>
<td>datanucleus.rdbms.query.fetchDirection</td>
<td>The direction in which the query results will be navigated. <strong>Applicable for RDBMS only</strong> {forward, reverse, unknown}</td>
</tr>
<tr>
<td>datanucleus.rdbms.query.resultSetType</td>
<td>Type of ResultSet to create. Note 1) Not all JDBC drivers accept all options. The values correspond directly to the ResultSet options. Note 2) Not all java.util.List operations are available for scrolling result sets. An Exception is raised when unsupported operations are invoked. <strong>Applicable for RDBMS only</strong>. {forward-only, scroll-sensitive, scroll-insensitive}</td>
</tr>
<tr>
<td>datanucleus.rdbms.query.resultSetConcurrency</td>
<td>Whether the ResultSet is readonly or can be updated. Not all JDBC drivers support all options. The values correspond directly to the ResultSet options. <strong>Applicable for RDBMS only</strong> {read-only, updateable}</td>
</tr>
<tr>
<td>datanucleus.rdbms.query.multivaluedFetch</td>
<td>How any multi-valued field should be fetched in a query. 'exists' means use an EXISTS statement hence retrieving all elements for the queried objects in one SQL with EXISTS to select the affected owner objects. 'none' means don't fetch container elements. <strong>Applicable for RDBMS only</strong> {exists, none}</td>
</tr>
<tr>
<td>datanucleus.rdbms.oracle.nlsSortOrder</td>
<td>Sort order for Oracle String fields in queries (BINARY disables native language sorting). <strong>Applicable for RDBMS only</strong> {LATIN, See Oracle documentation}</td>
</tr>
<tr>
<td>datanucleus.rdbms.mysql.engineType</td>
<td>Specify the default engine for any tables created in MySQL. <strong>Applicable to MySQL only</strong>. {InnoDB, valid engine for MySQL}</td>
</tr>
<tr>
<td>datanucleus.rdbms.mysql.collation</td>
<td>Specify the default collation for any tables created in MySQL. <strong>Applicable to MySQL only</strong></td>
</tr>
<tr>
<td>datanucleus.rdbms.mysql.characterSet</td>
<td>Specify the default charset for any tables created in MySQL. <strong>Applicable to MySQL only</strong></td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>datanucleus.rdbms.info rmix.useSerialForIdentity</td>
<td>Whether we are using SERIAL for identity columns (instead of SERIAL8). <strong>Applicable for RDBMS only</strong>. {true, false}</td>
</tr>
<tr>
<td>datanucleus.rdbms.dynamicSchemaUpdates</td>
<td>Whether to allow dynamic updates to the schema. This means that upon each insert/update the types of objects will be tested and any previously unknown implementations of interfaces will be added to the existing schema. <strong>Applicable for RDBMS only</strong> (true, false)</td>
</tr>
<tr>
<td>datanucleus.rdbms.omitDatabaseMetaDataGetColumns</td>
<td>Whether to bypass all calls to DatabaseMetaData.getColumns(). This JDBC method is called to get schema information, but on some JDBC drivers (e.g. Derby) it can take an inordinate amount of time. Setting this to true means that your datastore schema has to be correct and no checks will be performed. <strong>Applicable for RDBMS only</strong>. (true, false)</td>
</tr>
<tr>
<td>datanucleus.rdbms.sqlTableNamingStrategy</td>
<td>Name of the plugin to use for defining the names of the aliases of tables in SQL statements. <strong>Applicable for RDBMS only</strong> {alpha-scheme, t-scheme}</td>
</tr>
<tr>
<td>datanucleus.rdbms.tableColumnOrder</td>
<td>How we should order the columns in a table. The default is to put the fields of the owning class first, followed by superclasses, then subclasses. An alternative is to start from the base superclass first, working down to the owner, then the subclasses <strong>Applicable for RDBMS only</strong>. {owner-first, superclass-first}</td>
</tr>
<tr>
<td>datanucleus.rdbms.allo wColumnReuse</td>
<td>This property allows you to reuse columns for more than 1 field of a class. It is false by default to protect the user from erroneously typing in a column name. Additionally, if a column is reused, the user ought to think about how to determine which field is written to that column ... all reuse ought to imply the same value in those fields so it doesn't matter which field is written there, or retrieved from there. <strong>Applicable for RDBMS only</strong> (true, false)</td>
</tr>
<tr>
<td>datanucleus.rdbms.statementLogging</td>
<td>How to log SQL statements. The default is to log the statement and replace any parameters with the value provided in angle brackets. Alternatively you can log the statement with any parameters replaced by just the values (no brackets). The final option is to log the raw JDBC statement (with ? for parameters). <strong>Applicable for RDBMS only</strong> {values-in-brackets, values, jdbc}</td>
</tr>
<tr>
<td>datanucleus.rdbms.fetchUnloadedAutomatically</td>
<td>If enabled will, upon a request to load a field, check for any unloaded fields that are non-relation fields or 1-1/N-1 fields and will load them in the same SQL call. <strong>Applicable for RDBMS only</strong> (true, false)</td>
</tr>
<tr>
<td>datanucleus.cloud.storage.bucket</td>
<td>This is a mandatory property that allows you to supply the bucket name to store your data. <strong>Applicable for Google Storage, and AmazonS3 only</strong>.</td>
</tr>
<tr>
<td>datanucleus.hbase.relationUsesPersistableId</td>
<td>This defines how relations will be persisted. The legacy method would be just to store the &quot;id&quot; of the object. The default method is to use &quot;persistableId&quot; which is a form of the id but catering for datastore id and application id, and including the class of the target object to avoid subsequent lookups. <strong>Applicable for HBase only</strong>. (true, false)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description + Values</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>datanucleus.hbase.enforceUniquenessInApplication</td>
<td>Setting this property to true means that when a new object is persisted (and its identity is assigned), no check will be made as to whether it exists in the datastore and that the user takes responsibility for such checks. <strong>Applicable for HBase only.</strong> {true, false}</td>
</tr>
<tr>
<td>datanucleus.cassandra.enforceUniquenessInApplication</td>
<td>Setting this property to true means that when a new object is persisted (and its identity is assigned), no check will be made as to whether it exists in the datastore (since Cassandra does an UPSERT) and that the user takes responsibility for such checks. <strong>Applicable for Cassandra only.</strong> {true, false}</td>
</tr>
<tr>
<td>datanucleus.cassandra.compression</td>
<td>Type of compression to use for the Cassandra cluster. <strong>Applicable for Cassandra only.</strong> {none, snappy}</td>
</tr>
<tr>
<td>datanucleus.cassandra.metrics</td>
<td>Whether metrics are enabled for the Cassandra cluster. <strong>Applicable for Cassandra only.</strong> {true, false}</td>
</tr>
<tr>
<td>datanucleus.cassandra.ssl</td>
<td>Whether SSL is enabled for the Cassandra cluster. <strong>Applicable for Cassandra only.</strong> {true, false}</td>
</tr>
<tr>
<td>datanucleus.cassandra.socket.readTimeoutMillis</td>
<td>Socket read timeout for the Cassandra cluster. <strong>Applicable for Cassandra only.</strong></td>
</tr>
<tr>
<td>datanucleus.cassandra.socket.connectTimeoutMillis</td>
<td>Socket connect timeout for the Cassandra cluster. <strong>Applicable for Cassandra only.</strong></td>
</tr>
</tbody>
</table>

**DataNucleus EMF Properties**

DataNucleus provides the following properties for configuring EMF capabilities.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description + Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.jpa.addClassTransformer</td>
<td>When running with JPA in a JavaEE environment if you wish to have your classes enhanced at runtime you can enable this by setting this property to true. The default is to bytecode enhance your classes before deployment. {false, true}</td>
</tr>
<tr>
<td>datanucleus.jpa.persistenceContextType</td>
<td>JPA defines two lifecycle options. JavaEE usage defaults to &quot;transaction&quot; where objects are detached when a transaction is committed. JavaSE usage defaults to &quot;extended&quot; where objects are detached when the EntityManager is closed. This property allows control {transaction, extended}</td>
</tr>
<tr>
<td>datanucleus.jpa.txnMarkForRollbackOnException</td>
<td>JPA requires that any persistence exception should mark the current transaction for rollback. This persistence property allows that inflexible behaviour to be turned off leaving it to the user to decide when a transaction is needing to be rolled back. {true, false}</td>
</tr>
</tbody>
</table>
# Level 2 Cache

The *EntityManagerFactory* has an optional cache of all objects across all *EntityManager*s. This cache is called the Level 2 (L2) cache, and JPA doesn’t define whether this should be enabled or not. With DataNucleus it defaults to enabled. The user can configure the L2 cache if they so wish; by use of the persistence property `datanucleus.cache.level2.type`. You set this to "type" of cache required. You currently have the following options.

- **soft** - use the internal (soft reference based) L2 cache. **This is the default L2 cache in DataNucleus.** Provides support for the JPA interface of being able to put objects into the cache, and evict them when required. This option does not support distributed caching, solely running within the JVM of the client application. Soft references are held to non pinned objects.

- **weak** - use the internal (weak reference based) L2 cache. Provides support for the JPA interface of being able to put objects into the cache, and evict them when required. This option does not support distributed caching, solely running within the JVM of the client application. Weak references are held to non pinned objects.

- **javax.cache** - a simple wrapper to the Java standard "javax.cache" Temporary Caching API.

- **EHCache** - a simple wrapper to EHCache’s caching product.

- **EHCacheClassBased** - similar to the EHCache option but class-based.

- **OSCache** - a simple wrapper to OSCache’s caching product.

- **SwarmCache** - a simple wrapper to SwarmCache’s caching product.

- **Oracle Coherence** - a simple wrapper to Oracle’s Coherence caching product. Oracle’s caches support distributed caching, so you could, in principle, use DataNucleus in a distributed environment with this option.

- **spymemcached** - a simple wrapper to the "spymemcached" client for memcached caching product.

- **xmemcached** - a simple wrapper to the "xmemcached" client for memcached caching product.

- **cacheonix** - a simple wrapper to the Cacheonix distributed caching software.

- **none** - turn OFF Level 2 caching.

The weak, soft and javax.cache caches are available in the datanucleus-core plugin. The EHCache, OSCache, SwarmCache, Coherence, Cacheonix, and Memcache caches are available in the datanucleus-cache plugin.

In addition you can control the *mode* of operation of the L2 cache. You do this using the persistence property `datanucleus.cache.level2.mode` (or `javax.persistence.sharedCache.mode`). The default is *UNSPECIFIED* which means that DataNucleus will cache all objects of entities unless the entity is explicitly marked as not cacheable. The other options are *NONE* (don’t cache ever), *ALL* (cache all entities regardless of annotations), *ENABLE_SELECTIVE* (cache entities explicitly marked as cacheable), or *DISABLE_SELECTIVE* (cache entities unless explicitly marked as not cacheable - i.e same as our default).

Objects are placed in the L2 cache when you commit() the transaction of a EntityManager. This means that you only have datastore-persisted objects in that cache. Also, if an object is deleted...
during a transaction then at commit it will be removed from the L2 cache if it is present.

The Level 2 cache is a DataNucleus plugin point allowing you to provide your own cache where you require it. Use the examples of the EHCache, Coherence caches etc as reference.

**Controlling the Level 2 Cache**

The majority of times when using a JPA-enabled system you will not have to take control over any aspect of the caching other than specification of whether to use a Level 2 Cache or not. With JPA and DataNucleus you have the ability to control which objects remain in the cache. This is available via a method on the `EntityManagerFactory`.

```java
EntityManagerFactory emf = Persistence.createEntityManagerFactory(persUnitName, props);
Cache cache = emf.getCache();
```

The `Cache` interface provides methods to control the retention of objects in the cache. You have 2 types of methods

- **contains** - check if an object of a type with a particular identity is in the cache
- **evict** - used to remove objects from the Level 2 Cache

You can also control which classes are put into a Level 2 cache. So with the following JPA annotation `@Cacheable`, no objects of type `MyClass` will be put in the L2 cache.

```java
@Cacheable(false)
@Entity
public class MyClass
{
    ...
}
```

If you want to control which fields of an object are put in the Level 2 cache you can do this using an extension annotation on the field. This setting is only required for fields that are relationships to other persistable objects. Like this
public class MyClass {
    ...
    Collection values;
    @Extension(vendorName="datanucleus", key="cacheable", value="false")
    Collection elements;
}

So in this example we will cache "values" but not "elements". If a field is cacheable then

- If it is a persistable object, the "identity" of the related object will be stored in the Level 2 cache
  for this field of this object
- If it is a Collection of persistable elements, the “identity” of the elements will be stored in the
  Level 2 cache for this field of this object
- If it is a Map of persistable keys/values, the "identity" of the keys/values will be stored in the
  Level 2 cache for this field of this object

When pulling an object in from the Level 2 cache and it has a reference to another object
DataNucleus uses the "identity" to find that object in the Level 1 or Level 2 caches to re-relate the
objects.

**L2 Cache using javax.cache**

DataNucleus provides a simple wrapper to any compliant javax.cache implementation, for example
Apache Ignite or HazelCast. To enable this you should put a "javax.cache" implementation in your
CLASSPATH, and set the persistence properties

```properties
datanucleus.cache.level2.type=javax.cache
datanucleus.cache.level2.cacheName={cache name}
datanucleus.cache.level2.timeout={expiration time in millis - optional}
```

As an example, you could simply add the following to a Maven POM, together with those
persistence properties above to use HazelCast "javax.cache" implementation

```xml
<dependency>
    <groupId>javax.cache</groupId>
    <artifactId>cache-api</artifactId>
    <version>1.0.0</version>
</dependency>
<dependency>
    <groupId>com.hazelcast</groupId>
    <artifactId>hazelcast</artifactId>
    <version>3.7.3</version>
</dependency>
```
L2 Cache using EHCache

DataNucleus provides a simple wrapper to EHCache's own API caches (not the javax.cache API variant). To enable this you should set the persistence properties

```java
datanucleus.cache.level2.type=ehcache
datanucleus.cache.level2.cacheName={cache name}
datanucleus.cache.level2.configurationFile={EHCache configuration file (in classpath)}
```

The EHCache plugin also provides an alternative L2 Cache that is class-based. To use this you would need to replace "ehcache" above with "ehcacheclassbased".

L2 Cache using Spymemcached/Xmemcached

DataNucleus provides a simple wrapper to Spymemcached caches and Xmemcached caches. To enable this you should set the persistence properties

```java
datanucleus.cache.level2.type=spymemcached [or "xmemcached"]
datanucleus.cache.level2.cacheName={prefix for keys, to avoid clashes with other memcached objects}
datanucleus.cache.level2.memcached.servers=...
datanucleus.cache.level2.memcached.expireSeconds=...
```

datanucleus.cache.level2.memcached.servers is a space separated list of memcached hosts/ports, e.g. host:port host2:port. datanucleus.cache.level2.memcached.expireSeconds if not set or set to 0 then no expire

L2 Cache using Cacheonix

DataNucleus provides a simple wrapper to Cacheonix. To enable this you should set the persistence properties

```java
datanucleus.cache.level2.type=cacheonix
datanucleus.cache.level2.cacheName={cache name}
```

Note that you can optionally also specify

```java
datanucleus.cache.level2.timeout={timeout-in-millis (default=60)}
datanucleus.cache.level2.configurationFile={Cacheonix configuration file (in classpath)}
```

and define a cacheonix-config.xml like
L2 Cache using OSCache

DataNucleus provides a simple wrapper to OSCache's caches. To enable this you should set the persistence properties

```xml
<datanucleus.cache.level2.type=oscache>
<datanucleus.cache.level2 имени={cache name}>
```

L2 Cache using SwarmCache

DataNucleus provides a simple wrapper to SwarmCache's caches. To enable this you should set the persistence properties

```xml
<datanucleus.cache.level2.type=swarmcache>
<datanucleus.cache.level2 имени={cache name}>
```
L2 Cache using Oracle Coherence

DataNucleus provides a simple wrapper to Oracle's Coherence caches. This currently takes the NamedCache interface in Coherence and instantiates a cache of a user provided name. To enable this you should set the following persistence properties

```
datanucleus.cache.level2.type=coherence
datanucleus.cache.level2.cacheName={coherence cache name}
```

The Coherence cache name is the name that you would normally put into a call to CacheFactory.getCache(name). You have the benefits of Coherence's distributed/serialized caching. If you require more control over the Coherence cache whilst using it with DataNucleus, you can just access the cache directly via

```
DataStoreCache cache = pmf.getDataStoreCache();
NamedCache tangosolCache = ((TangosolLevel2Cache)cache).getTangosolCache();
```
Datastore Schema

Some datastores have a well-defined structure and when persisting/retrieving from these datastores you have to have this schema in place. DataNucleus provides various controls for creation of any necessary schema components. This creation can be performed as follows:

- At runtime, as a one-off generate-schema step. This is the recommended option since it is standard in JPA2.1
- One off task before running your application using SchemaTool
- At runtime, auto-generating tables as it requires them

The thing to remember when using DataNucleus is that the schema is under your control. DataNucleus does not impose anything on you as such, and you have the power to turn on/off all schema components. Some Java persistence tools add various types of information to the tables for persisted classes, such as special columns, or meta information. DataNucleus is very unobtrusive as far as the datastore schema is concerned. It minimises the addition of any implementation artifacts to the datastore, and adds nothing (other than any datastore identities, and version columns where requested) to any schema tables.

Schema Generation for persistence-unit

DataNucleus JPA allows you to generate the schema for your persistence-unit when creating an EMF. You can create, drop or drop then create the schema either directly in the datastore, or in scripts (DDL) as required. See the associated persistence properties (most of these only apply to RDBMS).

- `javax.persistence.schema-generation.database.action` which can be set to create, drop, drop-and-create or none to control the generation of the schema in the database.
- `javax.persistence.schema-generation.scripts.action` which can be set to create, drop, drop-and-create or none to control the generation of the schema as scripts (DDL). See also `javax.persistence.schema-generation.scripts.create.target` and `javax.persistence.schema-generation.scripts.drop.target` which will be generated using this mode of operation.
- `javax.persistence.schema-generation.scripts.create.target` - this should be set to the name of a DDL script file that will be generated when using `javax.persistence.schema-generation.scripts.action`
- `javax.persistence.schema-generation.scripts.drop.target` - this should be set to the name of a DDL script file that will be generated when using `javax.persistence.schema-generation.scripts.action`
- `javax.persistence.schema-generation.scripts.create.source` - set this to an SQL script of your own that will create some tables (prior to any schema generation from the persistable objects)
- `javax.persistence.schema-generation.scripts.drop.source` - set this to an SQL script of your own that will drop some tables (prior to any schema generation from the persistable objects)
- `javax.persistence.sql-load-script-source` - set this to an SQL script of your own that will insert any data that you require to be available when your EMF is initialised
Schema Auto-Generation at runtime

If you want to create the schema (tables + columns + constraints) during the persistence process, the property `datanucleus.schema.autoCreateAll` provides a way of telling DataNucleus to do this. It’s a shortcut to setting the other 3 properties to true. Thereafter, during calls to DataNucleus to persist classes or performs queries of persisted data, whenever it encounters a new class to persist that it has no information about, it will use the MetaData to check the datastore for presence of the "table", and if it doesn’t exist, will create it. In addition it will validate the correctness of the table (compared to the MetaData for the class), and any other constraints that it requires (to manage any relationships). If any constraints are missing it will create them.

- If you wanted to only create the "tables" required, and none of the "constraints" the property `datanucleus.schema.autoCreateTables` provides this, simply performing the tables part of the above.

- If you want to create any missing "columns" that are required, the property `datanucleus.schema.autoCreateColumns` provides this, validating and adding any missing columns.

- If you wanted to only create the "constraints" required, and none of the "tables" the property `datanucleus.schema.autoCreateConstraints` provides this, simply performing the "constraints" part of the above.

- If you want to keep your schema fixed (i.e don’t allow any modifications at runtime) then make sure that the properties `datanucleus.schema.autoCreate{XXX}` are set to `false`.

Schema Generation : Validation

DataNucleus can check any existing schema against what is implied by the MetaData.

The property `datanucleus.schema.validateTables` provides a way of telling DataNucleus to validate any tables that it needs against their current definition in the datastore. If the user already has a schema, and want to make sure that their tables match what DataNucleus requires (from the MetaData definition) they would set this property to `true`. This can be useful for example where you are trying to map to an existing schema and want to verify that you’ve got the correct MetaData definition.

The property `datanucleus.schema.validateColumns` provides a way of telling DataNucleus to validate any columns of the tables that it needs against their current definition in the datastore. If the user already has a schema, and want to make sure that their tables match what DataNucleus requires (from the MetaData definition) they would set this property to `true`. This will validate the precise column types and widths etc, including defaultability/nullability settings. Please be aware that many JDBC drivers contain bugs that return incorrect column detail information and so having this turned off is sometimes the only option (dependent on the JDBC driver quality).

The property `datanucleus.schema.validateConstraints` provides a way of telling DataNucleus to
validate any constraints (primary keys, foreign keys, indexes) that it needs against their current
definition in the datastore. If the user already has a schema, and want to make sure that their table
constraints match what DataNucleus requires (from the MetaData definition) they would set this
property to true.

**Schema Generation : Naming Issues**

Some datastores allow access to multiple "schemas" (such as with most RDBMS). DataNucleus will,
by default, use the "default" database schema for the Connection URL and user supplied. This may
cause issues where the user has been set up and in some databases (e.g Oracle) you want to write to
a different schema (which that user has access to). To achieve this in DataNucleus you would set the
persistence properties

```
datanucleus.mapping.Catalog={the_catalog_name}
datanucleus.mapping.Schema={the_schema_name}
```

This will mean that all RDBMS DDL and SQL statements will prefix table names with the necessary
catalog and schema names (specify which ones your datastore supports).

**Schema Generation : Column Ordering**

By default all tables are generated with columns in alphabetical order, starting with root class fields
followed by subclass fields (if present in the same table) etc. This is not part of JPA but DataNucleus
allows an extension to specify the relative position, such as

```
@ColumnPosition(3)
```

Note that the values of the position start at 0, and should be specified completely for all columns of
all fields.

**Schema : Read-Only**

If your datastore is read-only (you can’t add/update/delete any data in it), obviously you could just
configure your application to not perform these operations. An alternative is to set the EMF as read-
only, by setting the persistence property `datanucleus.ReadOnlyDatastore` to true.

From now on, whenever you perform a persistence operation that implies a change in datastore
data, the operation will throw a `PersistenceException`.

DataNucleus provides an additional control over the behaviour when an attempt is made to change
a read-only datastore. The default behaviour is to throw an exception. You can change this using
the persistence property `datanucleus.readOnlyDatastoreAction` with values of "EXCEPTION"
(default), and "IGNORE". "IGNORE" has the effect of simply ignoring all attempted updates to
readonly objects.

You can take this read-only control further and specify it just on specific classes. Like this
public class MyClass {

SchemaTool

DataNucleus SchemaTool currently works with RDBMS, HBase, Excel, OXXML, ODF, MongoDB, Cassandra datastores and is very simple to operate. It has the following modes of operation:

- **createDatabase** - create the specified database (catalog/schema) if the datastore supports that operation.
- **deleteDatabase** - delete the specified database (catalog/schema) if the datastore supports that operation.
- **create** - create all database tables required for the classes defined by the input data.
- **delete** - delete all database tables required for the classes defined by the input data.
- **deletecreate** - delete all database tables required for the classes defined by the input data, then create the tables.
- **validate** - validate all database tables required for the classes defined by the input data.
- **dbinfo** - provide detailed information about the database, it's limits and datatypes support. Only for RDBMS currently.
- **schemainfo** - provide detailed information about the database schema. Only for RDBMS currently.

In addition for RDBMS, the **create/delete** modes can be used by adding `"-ddlFile {filename}"` and this will then not create/delete the schema, but instead output the DDL for the tables/constraints into the specified file.

For the **create**, **delete** and **validate** modes DataNucleus SchemaTool accepts either of the following types of input:

- A set of MetaData and class files. The MetaData files define the persistence of the classes they contain. The class files are provided when the classes have annotations.
- The name of a **persistence-unit**. The **persistence-unit** name defines all classes, metadata files, and jars that make up that unit. Consequently, running DataNucleus SchemaTool with a persistence unit name will create the schema for all classes that are part of that unit.

⚠️ if using SchemaTool with a persistence-unit make sure you omit `javax.persistence.schema-generation` properties from your persistence-unit.*

Here we provide many different ways to invoke DataNucleus SchemaTool

- **Invoke it using Maven**, with the DataNucleus Maven plugin
- **Invoke it using Ant**, using the provided DataNucleus SchemaTool Ant task
• Invoke it manually from the command line
• Invoke it using the DataNucleus Eclipse plugin
• Invoke it programmatically from within an application

SchemaTool using Maven

If you are using Maven to build your system, you will need the DataNucleus Maven plugin. This provides 5 goals representing the different modes of DataNucleus SchemaTool. You can use the goals datanucleus:schema-create, datanucleus:schema-delete, datanucleus:schema-validate depending on whether you want to create, delete or validate the database tables. To use the DataNucleus Maven plugin you will may need to set properties for the plugin (in your pom.xml). For example

<table>
<thead>
<tr>
<th>Property</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>api</td>
<td>JDO</td>
<td>API for the metadata being used (JDO, JPA). Set this to JPA</td>
</tr>
<tr>
<td>ignoreMetaDataForMissingClasses</td>
<td>false</td>
<td>Whether to ignore when we have metadata specified for classes that aren't found</td>
</tr>
<tr>
<td>catalogName</td>
<td></td>
<td>Name of the catalog (mandatory when using createDatabase or deleteDatabase options)</td>
</tr>
<tr>
<td>schemaName</td>
<td></td>
<td>Name of the schema (mandatory when using createDatabase or deleteDatabase options)</td>
</tr>
<tr>
<td>persistenceUnitName</td>
<td></td>
<td>Name of the persistence-unit to generate the schema for (defines the classes and the properties defining the datastore). Mandatory</td>
</tr>
<tr>
<td>log4jConfiguration</td>
<td></td>
<td>Config file location for Log4J (if using it)</td>
</tr>
<tr>
<td>jdkLogConfiguration</td>
<td></td>
<td>Config file location for java.util.logging (if using it)</td>
</tr>
<tr>
<td>verbose</td>
<td>false</td>
<td>Verbose output?</td>
</tr>
<tr>
<td>fork</td>
<td>true</td>
<td>Whether to fork the SchemaTool process. Note that if you don't fork the process, DataNucleus will likely struggle to determine class names from the input filenames, so you need to use a persistence.xml file defining the class names directly.</td>
</tr>
<tr>
<td>ddlFile</td>
<td></td>
<td>Name of an output file to dump any DDL to (for RDBMS)</td>
</tr>
<tr>
<td>completeDdl</td>
<td>false</td>
<td>Whether to generate DDL including things that already exist? (for RDBMS)</td>
</tr>
</tbody>
</table>

So to give an example, I add the following to my pom.xml
<build>
  ...
  <plugins>
    <plugin>
      <groupId>org.datanucleus</groupId>
      <artifactId>datanucleus-maven-plugin</artifactId>
      <version>5.0.1</version>
      <configuration>
        <api>JPA</api>
        <persistenceUnitName>MyUnit</persistenceUnitName>
        <log4jConfiguration>${basedir}/log4j.properties</log4jConfiguration>
        <verbose>true</verbose>
      </configuration>
    </plugin>
  </plugins>
  ...
</build>

So with these properties when I run SchemaTool it uses properties from the file datanucleus.properties at the root of the Maven project. I am also specifying a log4j configuration file defining the logging for the SchemaTool process. I then can invoke any of the Maven goals

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mvn datanucleus:schema-createdatabase</td>
<td>Create the Database (catalog/schema)</td>
</tr>
<tr>
<td>mvn datanucleus:schema-deletedatabase</td>
<td>Delete the Database (catalog/schema)</td>
</tr>
<tr>
<td>mvn datanucleus:schema-create</td>
<td>Create the tables for the specified classes</td>
</tr>
<tr>
<td>mvn datanucleus:schema-delete</td>
<td>Delete the tables for the specified classes</td>
</tr>
<tr>
<td>mvn datanucleus:schema-deletecreate</td>
<td>Delete and create the tables for the specified classes</td>
</tr>
<tr>
<td>mvn datanucleus:schema-validate</td>
<td>Validate the tables for the specified classes</td>
</tr>
<tr>
<td>mvn datanucleus:schema-info</td>
<td>Output info for the Schema</td>
</tr>
<tr>
<td>mvn datanucleus:schema-dbinfo</td>
<td>Output info for the datastore</td>
</tr>
</tbody>
</table>

**Schematool using Ant**

An Ant task is provided for using DataNucleus SchemaTool. It has classname org.datanucleus.store.schema.SchemaToolTask, and accepts the following parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>values</th>
</tr>
</thead>
<tbody>
<tr>
<td>api</td>
<td>API that we are using in our use of DataNucleus. <strong>Set this to JPA typically</strong></td>
<td>JDO, JPA</td>
</tr>
<tr>
<td>persistenceUnit</td>
<td>Name of the persistence-unit that we should manage the schema for (defines the classes and the properties defining the datastore).</td>
<td></td>
</tr>
</tbody>
</table>
### Parameter Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>values</th>
</tr>
</thead>
<tbody>
<tr>
<td>mode</td>
<td>Mode of operation.</td>
<td>create, delete, validate, dbinfo, schemainfo, createDatabase, deleteDatabase</td>
</tr>
<tr>
<td>catalogName</td>
<td>Catalog name to use when used in createDatabase/deleteDatabase modes</td>
<td></td>
</tr>
<tr>
<td>schemaName</td>
<td>Schema name to use when used in createDatabase/deleteDatabase modes</td>
<td></td>
</tr>
<tr>
<td>verbose</td>
<td>Whether to give verbose output.</td>
<td>true, false</td>
</tr>
<tr>
<td>ddlFile</td>
<td>The filename where SchemaTool should output the DDL (for RDBMS).</td>
<td></td>
</tr>
<tr>
<td>completeDdl</td>
<td>Whether to output complete DDL (instead of just missing tables). Only used with ddlFile</td>
<td>true, false</td>
</tr>
</tbody>
</table>

The SchemaTool task extends the Apache Ant Java task, thus all parameters available to the Java task are also available to the SchemaTool task.

In addition to the parameters that the Ant task accepts, you will need to set up your CLASSPATH to include the classes and MetaData files, and to define the following system properties via the sysproperty parameter (not required when specifying the persistence props via the properties file, or when providing the persistence-unit)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>datanucleus.ConnectionDriverName</td>
<td>Name of JDBC driver class</td>
<td>✓</td>
</tr>
<tr>
<td>datanucleus.ConnectionURL</td>
<td>URL for the database</td>
<td>✓</td>
</tr>
<tr>
<td>datanucleus.ConnectionUserName</td>
<td>User name for the database</td>
<td>✓</td>
</tr>
<tr>
<td>datanucleus.ConnectionPassword</td>
<td>Password for the database</td>
<td>✓</td>
</tr>
<tr>
<td>datanucleus.Mapping</td>
<td>ORM Mapping name</td>
<td>×</td>
</tr>
<tr>
<td>log4j.configuration</td>
<td>Log4J configuration file, for SchemaTool's Log</td>
<td>×</td>
</tr>
</tbody>
</table>

So you could define something like the following, setting up the parameters schematool.classpath, datanucleus.ConnectionDriverName, datanucleus.ConnectionURL, datanucleus.ConnectionUserName, and datanucleus.ConnectionPassword to suit your situation.
Schematool Command-Line Usage

If you wish to call **DataNucleus SchemaTool** manually, it can be called as follows:

```java
java [-cp classpath] [system_props] org.datanucleus.store.schema.SchemaTool [modes] [options]
```

where `system_props` (when specified) should include:
- `Datanucleus.ConnectionURL=db_url`
- `Datanucleus.ConnectionDriverName=db_driver_name`
- `Datanucleus.ConnectionUserName=db_username`
- `Datanucleus.ConnectionPassword=db_password`
- `Log4j.configuration=file:{log4j.properties}` (optional)

where modes can be:
- `createDatabase` : create the specified database (if supported)
- `deleteDatabase` : delete the specified database (if supported)
- `create` : Create the tables specified by the mapping-files/class-files
- `delete` : Delete the tables specified by the mapping-files/class-files
- `deletecreate` : Delete the tables specified by the mapping-files/class-files
- `validate` : Validate the tables specified by the mapping-files/class-files
- `dbinfo` : Detailed information about the database
- `schemainfo` : Detailed information about the database schema

where options can be:
- `-catalog {catalogName}` : Catalog name when using
- `-schema {schemaName}` : Schema name when using
- `-api` : The API that is being used (default is JDO, but set this to JPA)
- `-pu {persistence-unit-name}` : Name of the persistence unit to manage the schema for
- `-ddlFile {filename}` : RDBMS - only for use with "create"/"delete" mode to dump the DDL to the specified file
- `-completeDdl` : RDBMS - when using "ddlFile" in "create" mode to get all DDL output and not just missing tables/constraints
- `-v` : verbose output

---

All classes, **MetaData files**, **persistence.xml** files **must be present in the CLASSPATH**. In terms of the schema to use, you either specify the "props" file (recommended), or you specify the System properties defining the database connection, or the properties in the "persistence-unit". You should only specify one of the modes above. Let's make a specific example and see the output from SchemaTool. So we have the following files in our application:
So we want to create the schema for our persistent classes. So let’s invoke **DataNucleus SchemaTool** to do this, from the top level of our project. In this example we’re using Linux (change the CLASSPATH definition to suit for Windows)

```
java -cp target/classes:lib/log4j.jar:lib/datanucleus-core.jar:lib/datanucleus-
    {datastore}.jar:lib/mysql-connector-java.jar
    -Dlog4j.configuration=file:log4j.properties
    org.datanucleus.store.schema.SchemaTool -create
    -api JPA -pu MyUnit

DataNucleus SchemaTool (version 5.0.0.release) : Creation of the schema

DataNucleus SchemaTool : Classpath
>> /home/andy/work/DataNucleus/samples/packofcards/target/classes
>> /home/andy/work/DataNucleus/samples/packofcards/lib/log4j.jar
>> /home/andy/work/DataNucleus/samples/packofcards/lib/datanucleus-core.jar
>> /home/andy/work/DataNucleus/samples/packofcards/lib/datanucleus-api-jpa.jar
>> /home/andy/work/DataNucleus/samples/packofcards/lib/javax.persistence.jar
>> /home/andy/work/DataNucleus/samples/packofcards/lib/datanucleus-rdbms.jar
>> /home/andy/work/DataNucleus/samples/packofcards/lib/mysql-connector-java.jar

DataNucleus SchemaTool : Persistence-Unit="MyUnit"

SchemaTool completed successfully
```

So as you see, **DataNucleus SchemaTool** prints out our input, the properties used, and finally a success message. If an error occurs, then something will be printed to the screen, and more information will be written to the log.

**SchemaTool API**

DataNucleus SchemaTool can also be called programmatically from an application. You need to get hold of the StoreManager and cast it to `SchemaAwareStoreManager`. The API is shown below.
package org.datanucleus.store.schema;

public interface SchemaAwareStoreManager {
    void createDatabase(String catalogName, String schemaName, Properties props);
    void deleteDatabase(String catalogName, String schemaName, Properties props);

    void createSchemaForClasses(Set<String> classNames, Properties props);
    void deleteSchemaForClasses(Set<String> classNames, Properties props);
    void validateSchemaForClasses(Set<String> classNames, Properties props);
}

So for example to create the schema for classes mydomain.A and mydomain.B you would do something like this

```java
EntityManagerFactory emf = Persistence.createEntityManagerFactory("MyUnit");
PersistenceNucleusContext nucCtx = (PersistenceNucleusContext)emf.unwrap(NucleusContext.class);
...
List classNames = new ArrayList();
classNames.add("mydomain.A");
classNames.add("mydomain.B");
try {
    Properties props = new Properties();
    // Set any properties for schema generation
    ((SchemaAwareStoreManager)nucCtx.getStoreManager()).createSchemaForClasses(classNames, props);
} catch(Exception e) {
    ...
}
```
Now that we have our EntityManagerFactory, providing the connection for our persistence-unit to our datastore, we need to obtain an EntityManager (EM) to manage the persistence of objects. Here we describe the majority of operations that you will are likely to need to know about.

An EntityManagerFactory is designed to be thread-safe. An EntityManager is not. If you set the persistence property datanucleus.Multithreaded this acts as a hint to the EMF to provide EntityManager(s) that are usable with multiple threads. While DataNucleus makes efforts to make this EntityManager usable with multiple threads, it is not guaranteed to work multi-threaded in all situations, particularly around second class collection/map fields.

To take an example, suppose we have the following (abbreviated) entities

```java
@Entity
public class Person {
    @Id
    long id;

    String firstName;
    String lastName;
}

@Entity
public class Account {
    @Id
    long id;

    @OneToOne
    Person person;
}
```

Opening/Closing an EntityManager

You obtain an EntityManager from the EntityManagerFactory as follows

```java
EntityManager em = emf.createEntityManager();
```

In the case of using container-managed JavaEE, you would instead obtain the EntityManager by injection
@PersistenceContext(unitName="myPU")
EntityManager em;

You then perform all operations that you need using this EntityManager and finally you must close it. Forgetting to close it will lead to memory/resource leaks.

```java
em.close();
```

In general you will be performing all operations on a EntityManager within a transaction, whether your transactions are controlled by your JavaEE container, by a framework such as Spring, or by locally defined transactions. In the examples below we will omit the transaction demarcation for clarity.

### Persisting an Object

The main thing that you will want to do with the data layer of a JPA-enabled application is persist your objects into the datastore. As we mentioned earlier, a EntityManagerFactory represents the datastore where the objects will be persisted. So you create a normal Java object in your application, and you then persist this as follows

```java
Person lincoln = new Person(1, "Abraham", "Lincoln");
em.persist(lincoln);
```

This will result in the object being persisted into the datastore, though clearly it will not be persistent until you commit the transaction. The Lifecycle State of the object changes from Transient to Persistent (after persist()), to Persistent/Detached (at commit).

### Persisting multiple Objects in one call

When you want to persist multiple objects with standard JPA you have to call persist multiple times. Fortunately DataNucleus extends this to take in a Collection or an array of entities, so you can do

```java
Collection<Person> coll = new HashSet<>();
coll.add(lincoln);
coll.add(mandela);
em.persist(coll);
```

As above, the objects are persisted to the datastore. The Lifecycle State of the objects change from Transient to Persistent (after persist()), to Persistent/Detached (at commit).
Finding an object by its identity

Once you have persisted an object, it has an "identity". This is a unique way of identifying it. When you specify the persistence for the entity you specified an id field (or fields, together with an IdClass) so you can create the identity from that. So what? Well the identity can be used to retrieve the object again at some other part in your application. So you pass the identity into your application, and the user clicks on some button on a web page and that button corresponds to a particular object identity. You can then go back to your data layer and retrieve the object as follows

```java
Person p = em.find(Person.class, 1);
```

which will try to retrieve the Person object with identity of 1. If there is no Person object with that identity then it returns null.

- the first argument could be a base class and the real object could be an instance of a subclass of that.

- the second argument is either the value of the single primary-key field (when it has only one @Id field), or is the value of the object-id-class (when it has multiple @Id fields).

Deleting an Object

When you need to delete an object that you had previous persisted, deleting it is simple. Firstly you need to get the object itself, and then delete it as follows

```java
Person lincoln = em.find(Person.class, 1); // Retrieves the object to delete
em.remove(lincoln);
```

Deleting multiple Objects

When you want to delete multiple objects with standard JPA you have to call remove multiple times. Fortunately DataNucleus extends this to take in a Collection or an array of entities, so you can do

```java
Collection<Person> people = new HashSet<>();
people.add(lincoln);
people.add(mandela);
em.remove(people);
```
Modifying a persisted Object

To modify a previously persisted object you take the object and update it in your code. If the object is in "detached" state (not managed by a particular EntityManager) then when you are ready to persist the changes you do the following

```java
Object updatedObj = em.merge(obj);
```

If however the object was already managed at the point of updating its fields, then

```java
Person lincoln = em.find(Person.class, 1); // "lincoln" is now managed by "em", and in "persistent" state.
lincoln.setAddress("The White House");
```

when the setAddress has been called, this is intercepted by DataNucleus, and the changes will be stored for persisting. There is no need to call any EntityManager method to push the changes. This is part of the mechanism known as transparent persistence.

Modifying multiple persisted Objects

When you want to attach multiple modified objects with standard JPA you have to call merge multiple times. Fortunately DataNucleus extends this to take in a Collection or an array of entities, so you can do

```java
Object updatedObj = em.merge(coll);
```

Refreshing a persisted Object

An application that has sole access to the datastore, in general, does not need to check for updated values from the datastore. In more complicated situations the datastore may be updated by another application for example, so it may be necessary at times to check for more up-to-date values for the fields of an entity. You do that like this

```java
em.refresh(lincoln);
```

This will do the following

- Refresh all fields that are to be eagerly fetched from the datastore
- Unload all loaded fields that are to be lazily fetched.

If the object had any changes they will be thrown away by this step, and replaced by the latest
Getting EntityManager for an object

JPA doesn’t provide a method for getting the EntityManager of an object as such. Fortunately DataNucleus provides the following

```java
import org.datanucleus.api.jpa.NucleusJPAHelper;
...
EntityManager em = NucleusJPAHelper.getEntityManager(obj);
```

If you have an `EntityManager` object and want to check if it is managing a particular object you can call

```java
boolean managedByThisEM = em.contains(lincoln);
```

Cascading Operations

When you have relationships between entities, and you persist one entity, by default the related entity will not be persisted. For each of the relation annotations `@OneToOne`, `@OneToMany`, `@ManyToOne` and `@ManyToMany` there is an attribute `cascade` which defaults to null but you can control what operations cascade (persist, remove, merge, detach, refresh).

Let’s use our example above, and create new `Person` and `Account` objects.

```java
Person lincoln = new Person(1, "Abraham", "Lincoln");
Account acct1 = new Account(1, lincoln); // Second argument sets the relation between the objects
```

now to persist them both we have two options. Firstly with the default cascade setting

```java
em.persist(lincoln);
em.persist(acct1);
```

The second option is to set the metadata on `Account` as
now we can simply do this (since the Account has a reference to Person);

em.persist(acct1);

Orphans

When an element is removed from a collection, or when a 1-1 relation is nulled, sometimes it is desirable to delete the other object. JPA defines a facility of removing "orphans" by specifying metadata for a 1-1 or 1-N relation. Let's take our example. In the above relation between Account and Person if we set the "person" field to null, this should mean that the Person record is deleted. So we could change the metadata to

So from now on, if we delete the Account we delete the Person, and if we set the "person" field of Account to null then we also delete the Person.

Managing Relationships

The power of a Java persistence solution like DataNucleus is demonstrated when persisting relationships between objects. There are many types of relationships.

• 1-1 relationships - this is where you have an object A relates to a second object B. The relation can be unidirectional where A knows about B, but B doesn't know about A. The relation can be bidirectional where A knows about B and B knows about A.

• 1-N relationships - this is where you have an object A that has a collection of other objects of type B. The relation can be unidirectional where A knows about the objects B but the Bs don't
The relation can be *bidirectional* where A knows about the objects B and the Bs know about A

- **N-1 relationships** - this is where you have an object B1 that relates to an object A, and an object B2 that relates to A also etc. The relation can be *unidirectional* where the A does not know about the Bs. The relation can be *bidirectional* where the A has a collection of the Bs. i.e a 1-N relationship but from the point of view of the element.

- **M-N relationships** - this is where you have objects of type A that have a collection of objects of type B and the objects of type B also have a collection of objects of type A. The relation is always *bidirectional* by definition

- **Derived Identity relationships** when you have a relation and part of the primary key of the related object is the other persistent object.

**Assigning Relationships**

When the relation is *unidirectional* you simply set the related field to refer to the other object. For example we have classes A and B and the class A has a field of type B. So we set it like this

```java
A a = new A();
B b = new B();
a.setB(b); // "a" knows about "b"
```

When the relation is *bidirectional* you **have to set both sides** of the relation. For example, we have classes A and B and the class A has a collection of elements of type B, and B has a field of type A. So we set it like this

```java
A a = new A();
B b1 = new B();
a.addElement(b1); // "a" knows about "b1"
b1.setA(a); // "b1" knows about "a"
```

With a *bidirectional* relation you must set both sides of the relation

**Persisting Relationships - Reachability**

To persist an object with JPA you call the `EntityManager` method `persist` (or `merge` if wanting to update a detached object). The object passed in will be persisted. By default all related objects will **not** be persisted with that object. You can however change this by specifying the `cascade` `PERSIST` (and/or `MERGE`) property for that field. With this the related object(s) would also be persisted (or updated with any new values if they are already persistent). This process is called **persistence-by-reachability**. For example we have classes A and B and class A has a field of type B and this field has the `cascade` property `PERSIST` set. To persist them we could do
A further example where you don’t have the *cascade* PERSIST set, but still want to persist both ends of a relation.

```java
A a = new A();
B b = new B();
a.setB(b);
em.persist(a); // "a" and "b" are provisionally persistent
```

Managed Relationships

As we have mentioned above, it is for the user to set both sides of a bidirectional relation. If they don’t and object A knows about B, but B doesn’t know about A then what is the persistence solution to do? It doesn’t know which side of the relation is correct. JPA doesn’t define the behaviour for this situation. DataNucleus has two ways of handling this situation. If you have the persistence property `datanucleus.manageRelationships` set to true then it will make sure that the other side of the relation is set correctly, correcting obvious omissions, and giving exceptions for obvious errors. If you set that persistence property to false then it will assume that your objects have their bidirectional relationships consistent and will just persist what it finds.

When performing management of relations there are some checks implemented to spot typical errors in user operations e.g add an element to a collection and then remove it (why?!). You can disable these checks using `datanucleus.manageRelationshipsChecks`, set to false.

Level 1 Cache

Each EntityManager maintains a cache of the objects that it has encountered (or have been "enlisted") during its lifetime. This is termed the **Level 1 Cache**. It is enabled by default and you should only ever disable it if you really know what you are doing. There are inbuilt types for the Level 1 (L1) Cache available for selection. DataNucleus supports the following types of L1 Cache:

- **weak** - uses a weak reference backing map. If JVM garbage collection clears the reference, then the object is removed from the cache.
- **soft** - uses a soft reference backing map. If the map entry value object is not being actively used, then garbage collection *may* garbage collect the reference, in which case the object is removed from the cache.
- **strong** - uses a normal HashMap backing. With this option all references are strong meaning that objects stay in the cache until they are explicitly removed by calling remove() on the cache.
You can specify the type of L1 Cache by providing the persistence property `datanucleus.cache.level1.type`. You set this to the value of the type required. If you want to remove all objects from the L1 cache programmatically you should use `em.clear()` but bear in mind the other things that this will impact on.

Objects are placed in the L1 Cache (and updated there) during the course of the transaction. This provides rapid access to the objects in use in the users application and is used to guarantee that there is only one object with a particular identity at any one time for that EntityManager. When the EntityManager is closed the cache is cleared.

Plugin The L1 cache is a DataNucleus plugin point allowing you to provide your own cache where you require it.
Object Lifecycle

During the persistence process an object goes through lifecycle changes. Below we demonstrate the primary object lifecycle changes for JPA. With JPA these lifecycles are referred to as "persistence contexts". There are two: transaction (default for JavaEE usage) and extended (default for JavaSE usage). DataNucleus allows control over which to use by specification of the persistence property datanucleus.jpa.persistenceContextType.

Transaction PersistenceContext

![Diagram of Transaction PersistenceContext]

A newly created object is transient. You then persist it and it becomes persistent. You then commit the transaction and it is detached for use elsewhere in the application, in detached state. You then attach any changes back to persistence and it becomes persistent again. Finally when you delete the object from persistence and commit that transaction it is in transient state.

Extended PersistenceContext

![Diagram of Extended PersistenceContext]

So a newly created object is transient. You then persist it and it becomes persistent. You then commit the transaction and it remains managed in persistent state. When you close the EntityManager it becomes detached. Finally when you delete the object from persistence and commit that transaction it is in transient state.

Detachment

When you detach an object (and its graph) either explicitly (using em.detach()) or implicitly via the PersistenceContext above, you need to be careful about which fields are detached. If you detach everything then you can end up with a huge graph that could impact on the performance of your application. On the other hand you need to ensure that you have all fields that you will be needing access to whilst detached. Should you access a field that was not detached an IllegalAccessException is thrown. All fields that are loaded will be detached so make sure you either load all required when retrieving the object using Entity Graphs or you access fields whilst...
Please note that some people interpret the JPA spec as implying that an object which has a primary key field set to a value as being detached. DataNucleus does not take this point of view, since the only way you can have a detached object is to detach it from persistence (i.e. it was once managed/attached). To reinforce our view of things, what state is an object in which has a primitive primary key field? Using the logic above of these other people any object of such a class would be in detached state (when not managed) since its PK is set. An object that has a PK field set is transient unless it was detached from persistence. Note that you can merge a transient object by setting the persistence property datanucleus.allowAttachOfTransient to true.

DataNucleus does not use the "CascadeType.DETACH" flag explicitly, and instead detaches the fields that are loaded (or marked for eager loading). In addition it allows the user to make use of the FetchPlan extension for controlling the fine details of what is loaded (and hence detached).

**Helper Methods**

JPA provides nothing to determine the lifecycle state of an object. Fortunately DataNucleus does consider this useful, so you can call the following

```java
String state = NucleusJPAHelper.getObjectState(entity);
boolean detached = NucleusJPAHelper.isDetached(entity);
boolean persistent = NucleusJPAHelper.isPersistent(entity);
boolean deleted = NucleusJPAHelper.isDeleted(entity);
boolean transactional = NucleusJPAHelper.isTransactional(entity);
```

When an object is detached it is often useful to know which fields are loaded/dirty. You can do this with the following helper methods

```java
Object[] detachedState = NucleusJPAHelper.getDetachedStateForObject(entity);
// detachedState[0] is the identity, detachedState[1] is the version when detached
// detachedState[2] is a BitSet for loaded fields
// detachedState[3] is a BitSet for dirty fields

String[] dirtyFieldNames = NucleusJPAHelper.getDirtyFields(entity, em);

String[] loadedFieldNames = NucleusJPAHelper.getLoadedFields(entity, em);
```
Transactions

Persistence operations performed by the EntityManager are typically managed in a transaction, allowing operations to be grouped together. A Transaction forms a unit of work. The Transaction manages what happens within that unit of work, and when an error occurs the Transaction can roll back any changes performed. Transactions can be managed by the users application, or can be managed by a framework (such as Spring), or can be managed by a JavaEE container. These are described below.

- **Local transactions**: managed using the JPA Transaction API
- **JTA transactions**: managed using the JTA UserTransaction API
- **Container-managed transactions**: managed by a JavaEE environment
- **Spring-managed transactions**: managed by SpringFramework
- **No transactions**: "auto-commit" mode

**Locally-Managed Transactions**

If using DataNucleus JPA in a JavaSE environment the normal type of transaction is RESOURCE_LOCAL. With this type of transaction the user manages the transactions themselves, starting, committing or rolling back the transaction. With these transactions with JPA you obtain an EntityTransaction from the EntityManager, and manage it like this.

flushTransaction();
commitTransaction();
rollbackTransaction();
EntityManager em = emf.createEntityManager();
EntityTransaction tx = em.getTransaction();
try {
    tx.begin();
    {users code to persist objects}
    tx.commit();
}
finally {
    if (tx.isActive())
    {
        tx.rollback();
    }
}
em.close();

In this case you have defined your persistence-unit to be like this

```xml
<persistence-unit name="MyUnit" transaction-type="RESOURCE_LOCAL">
    <properties>
        <property key="javax.persistence.jdbc.url" value="jdbc:mysql:..."/>
    </properties>
    ...
</persistence-unit>
```

or

```xml
<persistence-unit name="MyUnit" transaction-type="RESOURCE_LOCAL">
    <non-jta-data-source>java:comp/env/myDS</properties>
    ...
</persistence-unit>
```

The basic idea with Locally-Managed transactions is that you are managing the transaction start and end.

### JTA Transactions

Strict JPA does not support use of JTA transactions in a JavaSE environment. DataNucleus does however allow JTA transactions in a JavaSE environment.

The other type of transaction with JPA is using JTA. With this type, where you have a JTA data source from which you have a UserTransaction. This UserTransaction can have resources "joined"
to it. In the case of JPA, you have two scenarios. The first scenario is where you have the `UserTransaction` created before you create your `EntityManager`. The create of the `EntityManager` will automatically join it to the current `UserTransaction`, like this

```java
UserTransaction ut = (UserTransaction)new InitialContext().lookup("java:comp/UserTransaction");
ut.setTransactionTimeout(300);

EntityManager em = emf.createEntityManager();
try {
    ut.begin();
    .. perform persistence/query operations
    ut.commit();
} finally {
    em.close();
}
```

so we control the transaction using the `UserTransaction`.

The second scenario is where the `UserTransaction` is started after you have the `EntityManager`. In this case we need to join our `EntityManager` to the newly created `UserTransaction`, like this

```java
EntityManager em = emf.createEntityManager();
try {
    .. perform persistence, query operations
    UserTransaction ut = (UserTransaction)new InitialContext().lookup("java:comp/UserTransaction");
    ut.setTransactionTimeout(300);
    ut.begin();

    // Join the EntityManager operations to this UserTransaction
    em.joinTransaction();

    // Commit the persistence/query operations performed above
    ut.commit();
} finally {
    em.close();
}
```
In the JTA case you will have defined your persistence-unit to be like this

```xml
<persistence-unit name="MyUnit" transaction-type="JTA">
    ...
</persistence-unit>
```

**JTA TransactionManager**

Note that the JavaEE spec does not define a standard way of finding the JTA TransactionManager, and so all JavaEE containers have their own ways of handling this. DataNucleus provides a way of scanning the various methods to find that appropriate for the JavaEE container in use, but you can explicitly set the method of finding the TransactionManager, by use of the persistence properties datanucleus.jtaLocator and, if using this property set to custom_jndi then also datanucleus.jtaJndiLocation set to the JNDI location that stores the TransactionManager instance.

**Container-Managed Transactions**

When using a JavaEE container you are giving over control of the transactions to the container. Here you have **Container-Managed Transactions**. In terms of your code, you would do like the above examples **except** that you would OMIT the tx.begin(), tx.commit(), tx.rollback() since the JavaEE container will be doing this for you.

**Spring-Managed Transactions**

When you use a framework like Spring you would not need to specify the tx.begin(), tx.commit(), tx.rollback() since that would be done for you.

**No Transactions**

DataNucleus allows the ability to operate without transactions. With JPA this is enabled by default (see the 2 properties datanucleus.nontransactionalRead, datanucleus.nontransactionalWrite set to true, the default). This means that you can read objects and make updates outside of transactions. This is effectively an "auto-commit" mode.

```java
EntityManager em = emf.createEntityManager();

{users code to persist objects}

em.close();
```

When using non-transactional operations, you need to pay attention to the persistence property datanucleus.nontx.atomic. If this is true then any persist/delete/update will be committed to the datastore immediately. If this is false then any persist/delete/update will be queued up until the next transaction (or em.close()) and committed with that.
Flushing

During a transaction, depending on the configuration, operations don’t necessarily go to the datastore immediately, often waiting until commit. In some situations you need persists/updates/deletes to be in the datastore so that subsequent operations can be performed that rely on those being handled first. In this case you can flush all outstanding changes to the datastore using

```java
em.flush();
```

When you don’t have a transaction, calling flush() will throw a TransactionRequiredException.

A convenient vendor extension is to find which objects are waiting to be flushed at any time, like this

```java
List<ObjectProvider> objs = ((JPAEntityManager)pm).getExecutionContext().getObjectsToBeFlushed();
```

Transaction Isolation

DataNucleus also allows specification of the transaction isolation level. This is specified via the persistence property datanucleus.transactionIsolation. It accepts the standard JDBC values of

- read-uncommitted (1): dirty reads, non-repeatable reads and phantom reads can occur
- read-committed (2): dirty reads are prevented; non-repeatable reads and phantom reads can occur
- repeatable-read (4): dirty reads and non-repeatable reads are prevented; phantom reads can occur
- serializable (8): dirty reads, non-repeatable reads and phantom reads are prevented

The default is read-committed. If the datastore doesn’t support a particular isolation level then it will silently be changed to one that is supported. As an alternative you can also specify it on a per-transaction basis as follows (using the values in parentheses above).

```java
org.datanucleus.api.jpa.JPAEntityTransaction tx = (org.datanucleus.api.jpa.JPAEntityTransaction)pm.currentTransaction();
tx.setOption("transaction.isolation", 2);
```
Read-Only Transactions

Obviously transactions are intended for committing changes. If you come across a situation where you don't want to commit anything under any circumstances you can mark the transaction as "read-only" by calling

```java
EntityManager em = emf.createEntityManager();
Transaction tx = em.getTransaction();
try {
    tx.begin();
    tx.setRollbackOnly();
    {users code to persist objects}
    tx.rollback();
} finally {
    if (tx.isActive()) {
        tx.rollback();
    }
}
em.close();
```

Any call to `commit` on the transaction will throw an exception forcing the user to roll it back.

Transaction Savepoints (RDBMS)

JDBC provides the ability to specify a point in a transaction and rollback to that point if required, assuming the JDBC driver supports it. DataNucleus provides this as a vendor extension, as follows
import org.datanucleus.api.jpa.JPAEntityTransaction;

EntityManager em = emf.createEntityManager();
JPAEntityTransaction tx = (JPAEntityTransaction)pm.getTransaction();
try {
    tx.beginTransaction();
    {users code to persist objects}
    tx.setSavepoint("Point1");
    {more user code to persist objects}
    tx.rollbackToSavepoint("Point1");
    tx.releaseSavepoint("Point1");
    tx.rollback();
}
finally {
    if (tx.isActive()){
        tx.rollback();
    }
}
em.close();

Transaction Locking

A Transaction forms a unit of work. The Transaction manages what happens within that unit of work, and when an error occurs the Transaction can roll back any changes performed. There are the following locking types for a transaction.

- Transactions can lock all records in a datastore and keep them locked until they are ready to commit their changes. These are known as **Pessimistic (or datastore) Locking**.
- Transactions can simply assume that things in the datastore will not change until they are ready to commit, not lock any records and then just before committing make a check for changes. This is known as **Optimistic Locking**.

Pessimistic (Datastore) Locking

**Pessimistic** locking isn't directly supported in JPA but are provided as a vendor extension. It is suitable for short lived operations where no user interaction is taking place and so it is possible to block access to datastore entities for the duration of the transaction. You would select pessimistic locking by adding the persistence property `datanucleus.Optimistic` as `false`.

By default DataNucleus does not currently lock the objects fetched in pessimistic locking, but you
can configure this behaviour for RDBMS datastores by setting the persistence property `datanucleus.rdbms.useUpdateLock` to `true`. This will result in all "SELECT ... FROM ..." statements being changed to be "SELECT ... FROM ... FOR UPDATE". This will be applied only where the underlying RDBMS supports the "FOR UPDATE" syntax.

With pessimistic locking DataNucleus will grab a datastore connection at the first operation, and maintain it for the duration of the transaction. A single connection is used for the transaction (with the exception of any Value Generation operations which need datastore access, so these can use their own connection).

In terms of the process of pessimistic (datastore) locking, we demonstrate this below.

<table>
<thead>
<tr>
<th>Operation</th>
<th>DataNucleus process</th>
<th>Datastore process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start transaction</td>
<td>Prepare object (1) for persistence</td>
<td>Open connection. Insert the object (1) into the datastore</td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (2) for update</td>
<td>Update the object (2) into the datastore</td>
</tr>
<tr>
<td>Update object</td>
<td>Prepare object (3) for persistence</td>
<td>Insert the object (3) into the datastore</td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (4) for update</td>
<td>Update the object (4) into the datastore</td>
</tr>
<tr>
<td>Flush</td>
<td>No outstanding changes so do nothing</td>
<td></td>
</tr>
<tr>
<td>Perform query</td>
<td>Generate query in datastore language</td>
<td>Query the datastore and return selected objects</td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (5) for persistence</td>
<td>Insert the object (5) into the datastore</td>
</tr>
<tr>
<td>Update object</td>
<td>Prepare object (6) for update</td>
<td>Update the object (6) into the datastore</td>
</tr>
<tr>
<td>Commit transaction</td>
<td></td>
<td>Commit connection</td>
</tr>
</tbody>
</table>

So here whenever an operation is performed, DataNucleus pushes it straight to the datastore. Consequently any queries will always reflect the current state of all objects in use. However this mode of operation has no version checking of objects and so if they were updated by external processes in the meantime then they will overwrite those changes.

It should be noted that DataNucleus provides two persistence properties that allow an amount of control over when flushing happens with pessimistic locking

- `datanucleus.flush.mode` when set to MANUAL will try to delay all datastore operations until commit/flush.
- `datanucleus.datastoreTransactionFlushLimit` represents the number of dirty objects before a flush is performed. This defaults to 1.
Optimistic Locking

It is suitable for longer lived operations maybe where user interaction is taking place and where it would be undesirable to block access to datastore entities for the duration of the transaction. The assumption is that data altered in this transaction will not be updated by other transactions during the duration of this transaction, so the changes are not propagated to the datastore until commit()/flush(). The data is checked just before commit to ensure the integrity in this respect. The most convenient way of checking data for updates is to maintain a column on each table that handles optimistic locking data. The user will decide this when generating their MetaData.

Rather than placing version/timestamp columns on all user datastore tables, JPA allows the user to notate particular classes as requiring optimistic treatment. This is performed by specifying in MetaData or annotations the details of the field/column to use for storing the version - see versioning. With JPA you must have a field in your class ready to store the version.

In JPA you can read the version by inspecting the field marked as storing the version value.

In terms of the process of optimistic locking, we demonstrate this below.

<table>
<thead>
<tr>
<th>Operation</th>
<th>DataNucleus process</th>
<th>Datastore process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start transaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (1) for persistence</td>
<td></td>
</tr>
<tr>
<td>Update object</td>
<td>Prepare object (2) for update</td>
<td></td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (3) for persistence</td>
<td></td>
</tr>
<tr>
<td>Update object</td>
<td>Prepare object (4) for update</td>
<td></td>
</tr>
<tr>
<td>Flush</td>
<td>Flush all outstanding changes to the datastore</td>
<td>* Open connection * Version check of object (1) * Insert the object (1) in the datastore. * Version check of object (2) * Update the object (2) in the datastore. * Version check of object (3) * Insert the object (3) in the datastore. * Version check of object (4) * Update the object (4) in the datastore.</td>
</tr>
<tr>
<td>Perform query</td>
<td>Generate query in datastore language</td>
<td>Query the datastore and return selected objects</td>
</tr>
<tr>
<td>Persist object</td>
<td>Prepare object (5) for persistence</td>
<td></td>
</tr>
<tr>
<td>Update object</td>
<td>Prepare object (6) for update</td>
<td></td>
</tr>
<tr>
<td>Commit transaction</td>
<td>Flush all outstanding changes to the datastore</td>
<td>* Version check of object (5) * Insert the object (5) in the datastore * Version check of object (6) * Update the object (6) in the datastore. * Commit connection</td>
</tr>
</tbody>
</table>
Here no changes make it to the datastore until the user either commits the transaction, or they invoke flush(). The impact of this is that when performing a query, by default, the results may not contain the modified objects unless they are flushed to the datastore before invoking the query. Depending on whether you need the modified objects to be reflected in the results of the query governs what you do about that. If you invoke flush() just before running the query the query results will include the changes. The obvious benefit of optimistic locking is that all changes are made in a block and version checking of objects is performed before application of changes, hence this mode copes better with external processes updating the objects.

Please note that for some datastores (e.g RDBMS) the version check followed by update/delete is performed in a single statement. See also:

- JPA MetaData reference for <version> element
- JPA Annotations reference for @Version
Datastore Connections

DataNucleus utilises datastore connections as follows

- **EMF**: single connection at any one time for datastore-based value generation. Obtained just for the operation, then released.
- **EMF**: single connection at any one time for schema-generation. Obtained just for the operation, then released.
- **EM**: single connection at any one time. When in a transaction the connection is held from the point of retrieval until the transaction commits or rolls back. The exact point at which the connection is obtained is defined more fully below. When used for non-transactional operations the connection is obtained just for the specific operation (unless configured to retain it).

If you have multiple threads using the same *EntityManager* then you can get “ConnectionInUse” problems where another operation on another thread comes in and tries to perform something while that first operation is still in use. This happens because the JPA spec requires an implementation to use a single datastore connection at any one time. When this situation crops up the user ought to use multiple *EntityManagers*.

Another important aspect is use of queries for Optimistic transactions, or for non-transactional contexts. In these situations it isn’t possible to keep the datastore connection open indefinitely and so when the *Query* is executed the ResultSet is then read into memory making the queried objects available thereafter.

Transactional Context

For pessimistic/datastore transactions a connection will be obtained from the datastore when the first persistence operation is initiated. This datastore connection will be held for the duration of the transaction until such time as either *commit()* or *rollback()* are called.

For optimistic transactions the connection is only obtained when *flush()*/commit() is called. When *flush()* is called, or the transaction committed a datastore connection is finally obtained and it is held open until *commit/rollback* completes. When a datastore operation is required, the connection is typically released after performing that operation. So datastore connections, in general, are held for much smaller periods of time. This is complicated slightly by use of the persistence property *datanucleus.IgnoreCache*. When this is set to *false*, the connection, once obtained, is not released until the call to *commit()*/rollback().

For Neo4j/MongoDB a single connection is used for the duration of the EM for all transactional and nontransactional operations.

Nontransactional Context

When performing non-transactional operations, the default behaviour is to obtain a connection when needed, and release it after use. With RDBMS you have the option of retaining this
connection ready for the next operation to save the time needed to obtain it; this is enabled by setting the persistence property `datanucleus.connection.nontx.releaseAfterUse` to `false`.

For Neo4j/MongoDB a single connection is used for the duration of the EM for all transactional and nontransactional operations.

**User Connection**

DataNucleus provides a mechanism for users to access the native connection to the datastore, so that they can perform other operations as necessary. You obtain a connection as follows

```java
// Obtain the connection from the JDO implementation
ExecutionContext ec = em.unwrap(ExecutionContext.class);
NucleusConnection conn = ec.getStoreManager().getNucleusConnection(ec);
try {
    Object native = conn.getNativeConnection();
    // Cast "native" to the required type for the datastore, see below

    ... use the connection to perform some operations.
}
finally {
    // Hand the connection back to JPA
    conn.close();
}
```

For the datastores supported by DataNucleus, the "native" object is of the following types

- RDBMS: `java.sql.Connection`
- Excel: `org.apache.poi.hssf.usermodel.HSSFWorkbook`
- OOXML: `org.apache.poi.hssf.usermodel.XSSFWorkbook`
- ODF: `org.odftoolkit.odfdom.doc.OdfDocument`
- LDAP: `javax.naming.ldap.LdapContext`
- MongoDB: `com.mongodb.DB`
- HBase: NOT SUPPORTED
- JSON: NOT SUPPORTED
- XML: `org.w3c.dom.Document`
- Neo4j: `org.neo4j.graphdb.GraphDatabaseService`
- Cassandra: `com.datastax.driver.core.Session`
- NeoDatis: `org.neodatis.odb.ODB`
- GAE Datastore: `com.google.appengine.api.datastore.DatastoreService`
Things to bear in mind with this connection

- You **must** return the connection back to the EntityManager before performing any EntityManager operation. You do this by calling `conn.close()`
- If you don’t return the connection and try to perform an EntityManager operation which requires the connection then an Exception is thrown.

**Connection Pooling**

When you create an `EntityManagerFactory` using the connection URL, driver name and the username/password to use, this doesn’t necessarily pool the connections. For some of the supported datastores DataNucleus allows you to utilise a connection pool to efficiently manage the connections to the datastore. We currently provide support for the following

- **RDBMS**
  - Apache DBCP
  - Apache DBCP v2, we allow use of externally-defined DBCP2, but also provide a builtin DBCP v2.1.1
  - C3P0
  - Proxool
  - BoneCP
  - HikariCP
  - Tomcat
  - Manually creating a DataSource for a 3rd party software package
  - Custom Connection Pooling Plugins for RDBMS using the DataNucleus ConnectionPoolFactory interface
  - Using JNDI, and lookup a connection DataSource.
- **LDAP**
  - Using JNDI

You need to specify the persistence property `datanucleus.connectionPoolingType` to be whichever of the external pooling libraries you wish to use (or "None" if you explicitly want no pooling). DataNucleus provides two sets of connections to the datastore - one for transactional usage, and one for non-transactional usage. If you want to define a different pooling for nontransactional usage then you can also specify the persistence property `datanucleus.connectionPoolingType.nontx` to whichever is required.

**RDBMS : JDBC driver properties with connection pool**

If using RDBMS and you have a JDBC driver that supports custom properties, you can still use DataNucleus connection pooling and you need to specify the properties in with your normal persistence properties, but add the prefix `datanucleus.connectionPool.driver` to the property name that the driver requires. For example, if an Oracle JDBC driver accepts `defaultRowPrefetch`, then you would specify something like
and it will pass in `defaultRowPrefetch` as "50" into the driver used by the connection pool.

**RDBMS : Apache DBCP v2+**

DataNucleus provides a builtin version of DBCP2 to provide pooling. This is automatically selected if using RDBMS, unless you specify otherwise. An alternative is to use an external DBCP2. This is accessed by specifying the persistence property `datanucleus.connectionPoolingType`. To utilise DBCP2-based connection pooling we do this

```java
// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
props.setProperty("javax.persistence.jdbc.driver","com.mysql.jdbc.Driver");
props.setProperty("javax.persistence.jdbc.url","jdbc:mysql://localhost/myDB");
props.setProperty("javax.persistence.jdbc.user","login");
props.setProperty("javax.persistence.jdbc.password","password");
props.setProperty("datanucleus.connectionPoolingType", "dbcp2");
```

So the **EMF** will use connection pooling using DBCP version 2. To do this you will need `commons-dbcp2`, `commons-pool2` JARs to be in the CLASSPATH.

You can also specify persistence properties to control the actual pooling. The currently supported properties for DBCP2 are shown below

```plaintext
# Pooling of Connections
datanucleus.connectionPool.maxIdle=10
datanucleus.connectionPool.minIdle=3
datanucleus.connectionPool.maxActive=5
datanucleus.connectionPool.maxWait=60

datanucleus.connectionPool.testSQL=SELECT 1

datanucleus.connectionPool.timeBetweenEvictionRunsMillis=2400000
```

**RDBMS : Apache DBCP**

DataNucleus allows you to utilise a connection pool using DBCP (v1) to efficiently manage the connections to the datastore. It is recommended to use DBCP v2 instead of DBCP v1 for all JRE’s 1.7+. This is accessed by specifying the persistence property `datanucleus.connectionPoolingType` etc like this
// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
properties.setProperty("javax.persistence.jdbc.driver", "com.mysql.jdbc.Driver");
properties.setProperty("javax.persistence.jdbc.url", "jdbc:mysql://localhost/myDB");
properties.setProperty("javax.persistence.jdbc.user", "login");
properties.setProperty("javax.persistence.jdbc.password", "password");
properties.setProperty("datanucleus.connectionPoolingType", "DBCP");

So the EMF will use connection pooling using DBCP. To do this you will need commons-dbcp, commons-pool and commons-collections JARs to be in the CLASSPATH.

You can also specify persistence properties to control the actual pooling. The currently supported properties for DBCP are shown below

# Pooling of Connections
datanucleus.connectionPool.maxIdle=10
datanucleus.connectionPool.minIdle=3
datanucleus.connectionPool.maxActive=5
datanucleus.connectionPool.maxWait=60

# Pooling of PreparedStatements
datanucleus.connectionPool.maxStatements=0
datanucleus.connectionPool.testSQL=SELECT 1
datanucleus.connectionPool.timeBetweenEvictionRunsMillis=2400000
datanucleus.connectionPool.minEvictableIdleTimeMillis=1800000

RDBMS : C3P0

DataNucleus allows you to utilise a connection pool using C3P0 to efficiently manage the connections to the datastore. C3P0 is a third-party library providing connection pooling. This is accessed by specifying the persistence property datanucleus.connectionPoolingType. To utilise C3P0-based connection pooling we do this

// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
properties.setProperty("javax.persistence.jdbc.driver", "com.mysql.jdbc.Driver");
properties.setProperty("javax.persistence.jdbc.url", "jdbc:mysql://localhost/myDB");
properties.setProperty("javax.persistence.jdbc.user", "login");
properties.setProperty("javax.persistence.jdbc.password", "password");
properties.setProperty("datanucleus.connectionPoolingType", "C3P0");

So the EMF will use connection pooling using C3P0. To do this you will need the c3p0 JAR to be in the CLASSPATH. If you want to configure C3P0 further you can include a c3p0.properties in your CLASSPATH - see the C3P0 documentation for details.
You can also specify persistence properties to control the actual pooling. The currently supported properties for C3P0 are shown below

```
# Pooling of Connections
datanucleus.connectionPool.maxPoolSize=5
 datanucleus.connectionPool.minPoolSize=3
 datanucleus.connectionPool.initialPoolSize=3

# Pooling of PreparedStatements
datanucleus.connectionPool.maxStatements=20
```

RDBMS : Proxool

DataNucleus allows you to utilise a connection pool using Proxool to efficiently manage the connections to the datastore. Proxool is a third-party library providing connection pooling. This is accessed by specifying the persistence property `datanucleus.connectionPoolingType`. To utilise Proxool-based connection pooling we do this

```java
// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
properties.setProperty("javax.persistence.jdbc.driver","com.mysql.jdbc.Driver");
properties.setProperty("javax.persistence.jdbc.url","jdbc:mysql://localhost/myDB");
properties.setProperty("javax.persistence.jdbc.user","login");
properties.setProperty("javax.persistence.jdbc.password","password");
properties.setProperty("datanucleus.connectionPoolingType", "Proxool");
```

So the EMF will use connection pooling using Proxool. To do this you will need the proxool and commons-logging JARs to be in the CLASSPATH.

You can also specify persistence properties to control the actual pooling. The currently supported properties for Proxool are shown below

```
datanucleus.connectionPool.maxConnections=10
 datanucleus.connectionPool.testSQL=SELECT 1
```

RDBMS : BoneCP

DataNucleus allows you to utilise a connection pool using BoneCP to efficiently manage the connections to the datastore. BoneCP is a third-party library providing connection pooling. This is accessed by specifying the persistence property `datanucleus.connectionPoolingType`. To utilise BoneCP-based connection pooling we do this
// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
props.setProperty("javax.persistence.jdbc.driver","com.mysql.jdbc.Driver");
props.setProperty("javax.persistence.jdbc.url","jdbc:mysql://localhost/myDB");
props.setProperty("javax.persistence.jdbc.user","login");
props.setProperty("javax.persistence.jdbc.password","password");
props.setProperty("datanucleus.connectionPoolingType", "BoneCP");

So the EMF will use connection pooling using BoneCP. To do this you will need the bonecp JAR (and slf4j, google-collections) to be in the CLASSPATH.

You can also specify persistence properties to control the actual pooling. The currently supported properties for BoneCP are shown below

# Pooling of Connections
datanucleus.connectionPool.maxPoolSize=5
datanucleus.connectionPool.minPoolSize=3

# Pooling of PreparedStatements
datanucleus.connectionPool.maxStatements=20

RDBMS : HikariCP

DataNucleus allows you to utilise a connection pool using HikariCP to efficiently manage the connections to the datastore. HikariCP is a third-party library providing connection pooling. This is accessed by specifying the persistence property datanucleus.connectionPoolingType. To utilise this connection pooling we do this

// Specify our persistence properties used for creating our PMF
Properties props = new Properties();
props.setProperty("datanucleus.ConnectionDriverName","com.mysql.jdbc.Driver");
props.setProperty("datanucleus.ConnectionURL","jdbc:mysql://localhost/myDB");
props.setProperty("datanucleus.ConnectionUserName","login");
props.setProperty("datanucleus.ConnectionPassword","password");
props.setProperty("datanucleus.connectionPoolingType","HikariCP");

So the EMF will use connection pooling using HikariCP. To do this you will need the hikaricp JAR (and slf4j, javassist as required) to be in the CLASSPATH. You can also specify persistence properties to control the actual pooling. The currently supported properties for HikariCP are shown below
RDBMS: Tomcat

DataNucleus allows you to utilise a connection pool using Tomcat JDBC Pool to efficiently manage the connections to the datastore. This is accessed by specifying the persistence property `datanucleus.connectionPoolingType`. To utilise Tomcat-based connection pooling we do this

```
// Specify our persistence properties used for creating our EMF
Properties props = new Properties();
properties.setProperty("javax.persistence.jdbc.driver","com.mysql.jdbc.Driver");
properties.setProperty("javax.persistence.jdbc.url","jdbc:mysql://localhost/myDB");
properties.setProperty("javax.persistence.jdbc.user","login");
properties.setProperty("javax.persistence.jdbc.password","password");
properties.setProperty("datanucleus.connectionPoolingType","tomcat");
```

So the EMF will use a DataSource with connection pooling using Tomcat. To do this you will need the `tomcat-jdbc` JAR to be in the CLASSPATH.

You can also specify persistence properties to control the actual pooling, like with the other pools.

RDBMS: Manually create a DataSource ConnectionFactory

We could have used the built-in DBCP2 support which internally creates a DataSource ConnectionFactory, alternatively the support for external DBCP, C3P0, Proxool, BoneCP etc, however we can also do this manually if we so wish. Let's demonstrate how to do this with one of the most used pools Apache Commons DBCP

With DBCP you need to generate a `javax.sql.DataSource`, which you will then pass to DataNucleus. You do this as follows
Load the JDBC driver
Class.forName(dbDriver);

Create the actual pool of connections
ObjectPool connectionPool = new GenericObjectPool(null);

Create the factory to be used by the pool to create the connections
ConnectionFactory connectionFactory = new DriverManagerConnectionFactory(dbURL, dbUser, dbPassword);

Create a factory for caching the PreparedStatements
KeyedObjectPoolFactory kpf = new StackKeyedObjectPoolFactory(null, 20);

Wrap the connections with pooled variants
PoolableConnectionFactory pcf = new PoolableConnectionFactory(connectionFactory, connectionPool, kpf, null, false, true);

Create the datasource
DataSource ds = new PoolingDataSource(connectionPool);

Create our EMF
Map properties = new HashMap();
properties.put("datanucleus.ConnectionFactory", ds);
EntityManagerFactory emf = Persistence.createEntityManagerFactory("myPersistenceUnit", properties);

Note that we haven't passed the dbUser and dbPassword to the EMF since we no longer need to specify them - they are defined for the pool so we let it do the work. As you also see, we set the data source for the EMF. Thereafter we can sit back and enjoy the performance benefits. Please refer to the documentation for DBCP for details of its configurability (you will need commons-dbcp, commons-pool, and commons-collections in your CLASSPATH to use this above example).

RDBMS : Lookup a DataSource using JNDI

DataNucleus allows you to use connection pools (java.sql.DataSource) bound to a javax.naming.InitialContext with a JNDI name. You first need to create the DataSource in the container (application server/web server), and secondly you specify the jta-data-source in the persistence-unit with the DataSource JNDI name. Please read more about this in RDBMS DataSources.

LDAP : JNDI

If using an LDAP datastore you can use the following persistence properties to enable connection pooling

datanucleus.connectionPoolingType=JNDI
Once you have turned connection pooling on if you want more control over the pooling you can also set the following persistence properties:

- `datanucleus.connectionPool.maxPoolSize`: max size of pool
- `datanucleus.connectionPool.initialPoolSize`: initial size of pool

**RDBMS : Data Sources**

DataNucleus allows use of a *data source* that represents the datastore in use. This is often just a URL defining the location of the datastore, but there are in fact several ways of specifying this *data source* depending on the environment in which you are running.

- **Nonmanaged Context - Java Client**
- **Managed Context - Servlet**
- **Managed Context - JavaEE**

**Java Client Environment : Non-managed Context**

DataNucleus permits you to take advantage of using database connection pooling that is available on an application server. The application server could be a full JEE server (e.g WebLogic) or could equally be a servlet engine (e.g Tomcat, Jetty). Here we are in a non-managed context, and we use the following properties when creating our EntityManagerFactory, and refer to the JNDI data source of the server.

If the data source is available in WebLogic, the simplest way of using a data source outside the application server is as follows.

```java
Map ht = new Hashtable();
ht.put(Context.INITIAL_CONTEXT_FACTORY,"weblogic.jndi.WLInitialContextFactory");
ht.put(Context.PROVIDER_URL,"t3://localhost:7001");
Context ctx = new InitialContext(ht);
DataSource ds = (DataSource) ctx.lookup("jdbc/datanucleus");

Map properties = new HashMap();
properties.setProperty("datanucleus.ConnectionFactory",ds);
EntityManagerFactory emf = ...
```

If the data source is available in Websphere, the simplest way of using a data source outside the application server is as follows.
Map ht = new Hashtable();
ht.put(Context.INITIAL_CONTEXT_FACTORY, "com.ibm.websphere.naming.WsnInitialContextFactory");
ht.put(Context.PROVIDER_URL, "iiop://server:orb port");

Context ctx = new InitialContext(ht);
DataSource ds = (DataSource) ctx.lookup("jdbc/datanucleus");

Map properties = new HashMap();
properties.setProperty("datanucleus.ConnectionFactory", ds);
EntityManagerFactory emf = ...

### Servlet Environment: Managed Context

As an example of setting up such a JNDI data source for Tomcat 5.0, here we would add the following file to $TOMCAT/conf/Catalina/localhost/ as datanucleus.xml
With this Tomcat JNDI data source we would then specify the data source (name) as `java:comp/env/jdbc/datanucleus`.

```java
Properties properties = new Properties();
properties.setProperty("javax.persistence.jtaDataSource","java:comp/env/jdbc/datanucleus");
EntityManagerFactory emf = ...
```

**JavaEE : Managed Context**

As in the above example, we can also run in a managed context, in a JavaEE/Servlet environment, and here we would make a minor change to the specification of the JNDI data source depending on
the application server or the scope of the JNDI: global or component.

Using JNDI deployed in global environment:

```java
Properties properties = new Properties();
properties.setProperty("javax.persistence.jtaDataSource","jdbc/datanucleus");
EntityManagerFactory emf = ...
```

Using JNDI deployed in component environment:

```java
Properties properties = new Properties();
properties.setProperty("javax.persistence.jtaDataSource","java:comp/env/jdbc/datanucleus");
EntityManagerFactory emf = ...
```
Multitenancy

On occasion you need to share a data model with other user-groups or other applications and where the model is persisted to the same structure of datastore. There are three ways of handling this with DataNucleus.

- **Separate Database per Tenant** - have a different database per user-group/application. In this case you will have a separate EMF for each database, and manage use of the appropriate EMF yourself.

- **Separate Schema per Tenant** - as the first option, except use different schemas. In this case you will have a separate EMF for each database schema, and manage use of the appropriate EMF yourself.

- **Same Database/Schema but with a Discriminator in affected Table(s)**. In this case you will have a single EMF, and DataNucleus will manage selecting appropriate data for the tenant in question. This is described below.

Multitenancy via Discriminator in Table

Applicable to RDBMS, HBase, MongoDB, Neo4j, Cassandra

If you specify the persistence property `datanucleus.tenantId` as an identifier for your user-group/application then DataNucleus will know that it needs to provide a tenancy discriminator to all primary tables of persisted classes. This discriminator is then used to separate the data of the different user-groups.

By default this will add a column `TENANT_ID` to each primary table, of String-based type. You can control this by specifying extension metadata for each persistable class

```xml
<class name="MyClass">
    <extension vendor-name="datanucleus" key="multitenancy-column-name" value="TENANT"/>
    <extension vendor-name="datanucleus" key="multitenancy-column-length" value="24"/>
    ...
</class>
```

or using annotations

```java
@Entity
@MultiTenant(column="TENANT", columnLength=24)
public class MyClass
{
    ...
}
```
In all subsequent use of DataNucleus, any "insert" to the primary "table"(s) will also include the TENANT column value. Additionally any query will apply a WHERE clause restricting to a particular value of TENANT column.

If you have enabled multi-tenancy as above but want to disable multitenancy on a class, just specify the following metadata

```xml
<class name="MyClass">
  <extension vendor-name="datanucleus" key="multitenancy-disable" value="true"/>
  ...
</class>
```

or using annotations

```java
@PersistenceCapable
@MultiTenant(disable=true)
public class MyClass
{
  ...
}
```

Note that the Tenant ID can be set in one of three ways.

- Per EntityManagerFactory: just set the persistence property `datanucleus.tenantId` when you start up the EMF, and all access for this EMF will use this Tenant ID
- Per EntityManager: set the persistence property `datanucleus.tenantId` when you start up the EMF as the default Tenant ID, and set a property on any EntityManager that you want a different Tenant ID specifying for. Like this

```java
EntityManager em = emf.createEntityManager();
... // All operations will apply to default tenant specified in persistence property for EMF
em.close();

EntityManager em1 = emf.createEntityManager();
em1.setProperty("datanucleus.tenantId", "John");
... // All operations will apply to tenant "John"
em1.close();

EntityManager em2 = emf.createEntityManager();
em2.setProperty("datanucleus.tenantId", "Chris");
... // All operations will apply to tenant "Chris"
em2.close();
```

- Per datastore access: When creating the EMF set the persistence property `datanucleus.tenantProvider` and set it to an instance of `org.datanucleus.store.schema.MultiTenancyProvider`
public interface MultiTenancyProvider
{
    String getTenantId(ExecutionContext ec);
}

Now the programmer can set a different Tenant ID for each datastore access, maybe based on some session variable for example?
Bean Validation

The Bean Validation API (JSR0303/JSR0349) can be hooked up with JPA so that you have validation of an object's values prior to persistence, update and deletion. To do this:

- Put the `javax.validation` validation-api jar in your CLASSPATH, along with the Bean Validation implementation jar of your choice (e.g. Apache BVal).
- Set the persistence property `javax.persistence.validation.mode` to one of `auto` (default), `none`, or `callback`.
- Optionally set the persistence property(s) `javax.persistence.validation.group.pre-persist`, `javax.persistence.validation.group.pre-update`, `javax.persistence.validation.group.pre-remove` to fine-tune the behaviour (the default is to run validation on pre-persist and pre-update if you don't specify these).
- Use JPA as you normally would for persisting objects.

To give a simple example of what you can do with the Bean Validation API:

```java
@Entity
public class Person {
    @Id
    @NotNull
    private Long id;

    @NotNull
    @Size(min = 3, max = 80)
    private String name;

    ...
}
```

So we are validating that instances of the `Person` class will have an "id" that is not null and that the "name" field is not null and between 3 and 80 characters. If it doesn't validate then at persist/update an exception will be thrown. You can add bean validation annotations to classes marked as `@Entity`, `@MappedSuperclass` or `@Embeddable`.

A further use of the Bean Validation annotations `@Size(max=...)` and `@NotNull` is that if you specify these then you have no need to specify the equivalent JPA attributes since they equate to the same thing.
**Entity Graphs**

When an object is retrieved from the datastore by JPA typically not all fields are retrieved immediately. This is because for efficiency purposes only particular field types are retrieved in the initial access of the object, and then any other objects are retrieved when accessed (lazy loading). The group of fields that are loaded is called an **entity graph**. There are 3 types of "entity graphs" to consider

- **Default Entity Graph**: implicitly defined in all JPA specs, specifying the *fetch* setting for each field/property (LAZY/EAGER).
- **Named Entity Graphs**: a new feature in JPA 2.1 allowing the user to define *Named Entity Graphs* in metadata, via annotations or XML
- **Unnamed Entity Graphs**: a new feature in JPA 2.1 allowing the user to define Entity Graphs via the JPA API at runtime

**Default Entity Graph**

JPA provides an initial entity graph, comprising the fields that will be retrieved when an object is retrieved if the user does nothing to define the required behaviour. You define this "default" by setting the *fetch* attribute in metadata for each field/property.

**Named Entity Graphs**

You can predefine **Named Entity Graphs** in metadata which can then be used at runtime when retrieving objects from the datastore (via find/query). For example, if we have the following class

```java
class MyClass
{
    String name;
    Set coll;
    MyOtherClass other;
}
```

and we want to have the option of the *other* field loaded whenever we load objects of this class, we define our annotations as

```java
@Entity
@NamedEntityGraph(name="includeOther", attributeNodes={@NamedAttributeNode("other")})
public class MyClass
{
    ...
}
```

So we have defined an EntityGraph called "includeOther" that just includes the field with name *other*. We can retrieve this and then use it in our persistence code, as follows
EntityGraph includeOtherGraph = em.getEntityGraph("includeOther");

Properties props = new Properties();
props.put("javax.persistence.loadgraph", includeOtherGraph);
MyClass myObj = em.find(MyClass.class, id, props);

Here we have made use of the EntityManager.find method and provided the property javax.persistence.loadgraph to be our EntityGraph. This means that it will fetch all fields in the default EntityGraph, plus all fields in the includeOther EntityGraph. If we had provided the property javax.persistence.fetchgraph set to our EntityGraph it would have fetched just the fields defined in that EntityGraph.

Note that you can also make use of EntityGraphs when using the JPA Query API, specifying the same properties above but as query hints.

Unnamed Entity Graphs

You can define Entity Graphs at runtime, programmatically. For example, if we have the following class

class MyClass
{
    String name;
    Set coll;
    MyOtherClass other;
}

and we want to have the option of the other field loaded whenever we load objects of this class, we do the following

EntityGraph includeOtherGraph = em.createEntityGraph(MyClass.class);
includeOtherGraph.addAttributeNodes("other");

So we have defined an EntityGraph that just includes the field with name other. We can then use this at runtime in our persistence code, as follows

Properties props = new Properties();
props.put("javax.persistence.loadgraph", includeOtherGraph);
MyClass myObj = em.find(MyClass.class, id, props);

Here we have made use of the EntityManager.find method and provided the property javax.persistence.loadgraph to be our EntityGraph. This means that it will fetch all fields in the default EntityGraph, plus all fields in this EntityGraph. If we had provided the property javax.persistence.fetchgraph set to our EntityGraph it would have fetched just the fields defined in that EntityGraph.
Note that you can also make use of EntityGraphs when using the JPA Query API, specifying the same properties above but as query hints, like this

```java
EntityGraph<MyClass> eg = em.createEntityGraph(MyClass.class);
eg.addAttributeNodes("id");
eg.addAttributeNodes("name");
eg.addAttributeNodes("other");
Subgraph<MyOtherClass> myOtherClassGraph = eg.addSubgraph("other", MyOtherClass.class);
myOtherClass.addAttributeNodes("name");

Query q = em.createQuery("SELECT m FROM MyClass m");
q.setHint("javax.persistence.fetchgraph", eg);
List<MyClass> results = q.getResultList();
```
Lifecycle Callbacks

JPA defines a mechanism whereby an Entity can be marked as a listener for lifecycle events. Alternatively a separate entity listener class can be defined to receive these events. Thereafter when entities of the particular class go through lifecycle changes events are passed to the provided methods. Let’s look at the two different mechanisms

Entity Callbacks

An Entity itself can have several methods defined to receive events when any instances of that class pass through lifecycles changes. Let’s take an example

```java
@Entity
public class Account {
    @Id
    Long accountId;

    Integer balance;
    boolean preferred;

    public Integer getBalance() { ... }

    @PrePersist
    protected void validateCreate()
    {
        if (getBalance() < MIN_REQUIRED_BALANCE)
        {
            throw new AccountException("Insufficient balance to open an account");
        }
    }

    @PostLoad
    protected void adjustPreferredStatus()
    {
        preferred = (getBalance() >= AccountManager.getPreferredStatusLevel());
    }
}
```

So in this example just before any "Account" object is persisted the `validateCreate` method will be called. In the same way, just after the fields of any "Account" object are loaded the `adjustPreferredStatus` method is called. Very simple.

You can register callbacks for the following lifecycle events

- PrePersist
- PostPersist
The only other rule is that any method marked to be a callback method has to take no arguments as input, and have void return.

**Entity Listener**

As an alternative to having the actual callback methods in the Entity class itself you can define a separate class as an *EntityListener*. So let's take the example shown before and do it for an *EntityListener*.

```java
@Entity
@EntityListeners(org.datanucleus.MyEntityListener.class)
public class Account {
  @Id
  Long accountId;

  Integer balance;
  boolean preferred;

  public Integer getBalance() { ... }
}
```

```java
public class MyEntityListener {
  @PostPersist
  public void newAccountAlert(Account acct) {
    ... do something when we get a new Account
  }
}
```

So we define our "Account" entity as normal but mark it with an *EntityListener*, and then in the *EntityListener* we define the callbacks we require. As before we can define any of the 7 callbacks as we require. The only difference is that the callback method has to take an argument of type "Object" that it will be called for, and have void return.
JavaEE Environments

JPA is designed to allow easy deployment into a JavaEE container. The JavaEE container takes care of integration of the JPA implementation (DataNucleus), so there is no JCA connector required.

Key points to remember when deploying your JPA application to use DataNucleus under JavaEE

- Define a JTA datasource for your persistence operations
- Define a non-JTA datasource for your schema and sequence operations. These are cross-EntityManager and so need their own datasource that is not affected by transactions.

Individual guides for specific JavaEE servers are listed below. If you have a guide for some other server, please notify us and it will be added to this list.

JBoss AS7

This guide was provided by Nicolas Seyvet. It is linked to from the JBoss docs.

JBoss AS7 is a recent JavaEE server from JBoss. Despite searching in multiple locations, I could not find a comprehensive guide on how to switch from the default JBoss Hibernate JPA provider to Datanucleus (3). If you try this guide, please PM the author (or add a comment) and let me know how it worked out. Your feedback will be used to improve this guide. This guide is cross-referenced as part of the JBoss JPA Reference Guide.

Download JBoss AS 7 and DataNucleus 3.2+

JBoss : At the time I am writing this "How To", the latest JBoss AS available from the main JBoss community site is 7.1.1.Final aka Brontes. In this guide, the latest 7.x SNAPSHOT was used but the steps will work with any JBoss 7.x version.

DataNucleus : Version 4.0.0 was used, from SourceForge

Install JBoss AS 7

Install JBoss AS 7 by unzipping the downloaded JBoss zip file in the wanted folder to be used as the JBoss home root folder (example: /local/jboss). From this point, the path where JBoss is unzipped will be referred to as $JBoss_HOME.

Note: JBoss AS 7 configuration is controlled by either standalone.xml ($JBoss_HOME/standalone/configuration) or domain.xml ($JBoss_HOME/domain/configuration) depending on the operation mode (standalone or domain) of the application server. The domain mode is typically used for cases where the AS is deployed in a cluster environment. In this tutorial, a single AS instance is used, as such, the standalone mode is selected and all configuration changes will be applied to the standalone.xml file.

Start JBoss

To start the server, use:
On Linux:

$ cd $JBoss_HOME/bin/
$ ./standalone.sh

On Windows:

$ cd $JBoss_HOME/bin/
$ standalone.bat

After a few seconds, a message should indicate the server is started.

17:23:00,251 INFO  [org.jboss.as] (Controller Boot Thread) JBAS015874: JBoss AS 7.2.0.Alpha1-SNAPSHOT "Steropes" started in 3717ms - Started 198 of 257 services (56 services are passive or on-demand)

To verify, access the administration GUI located at http://localhost:9990/, and expect to see a “Welcome to AS 7” banner. On the first start up, a console will show that an admin user must first be created in order to be able to access the management UI. Follow the steps and create a user.

On Linux:

$JBOSS_HOME/bin$ add-user.sh

On Windows:

$JBOSS_HOME/bin$ add-user.bat

Add a JDBC DataSource (Optional)

This step is only necessary if an RDBMS solution is used as a data store, or if external drivers are required. This tutorial will use MySQL as the RDBMS storage, and the required drivers and data source will be added. For more information, about data sources under JBoss AS 7, refer to the JBoss docs

Add MySQL drivers

For MySQL, it is recommended to use Connector/J, which can be found here. This tutorial uses version 5.1.20.

JBoss uses OSGI to define a set of modules, further info about class loading in JBoss. In short, the configuration files binds the services and the modules, defining what is available in the class loader for a specific service or application.

While dropping the drivers in the $JBoss_HOME/standalone/deployments directory works, this
approach is not recommended. The proper approach is to add the drivers by defining a new module containing the required libraries. The full instructions are available under here.

Short walk through for MySQL:

- Get the drivers
- Create a "mysql" directory under $JBOSS_HOME/modules/com/
- Create a "main" directory under $JBOSS_HOME/modules/com/mysql
- Copy the "mysql-connector-java-5.1.20-bin.jar" drivers under $JBOSS_HOME/modules/com/mysql/main
- Add a module.xml file under $JBOSS_HOME/modules/com/mysql/main

```xml
<?xml version="1.0" encoding="UTF-8"?>
<module xmlns="urn:jboss:module:1.0" name="com.mysql">
  <resources>
    <resource-root path="mysql-connector-java-5.1.20-bin.jar"/>
  </resources>
  <dependencies>
    <module name="javax.api"/>
  </dependencies>
</module>
```

The name is important as it defines the module name and is used in the standalone.xml configuration file. Now, let's say the URL to the MySQL database to be used is "jdbc:mysql://localhost:3306/simple", there are three ways to add that to the server, either through the management console at localhost or, by modifying the standalone.xml configuration file, or by using the Command Line Interface (CLI).

Let's modify the standalone.xml file. Verify the AS is stopped. Open standalone.xml for editing. Search for "subsystem xmlns="urn:jboss:domain:datasources:1.1", the section defines data sources and driver references. Let's add our data source and drivers. Add the following in the datasources section:
The above defines two data sources (MySQL-DS and MySQL-DS-NonJTA) referring to the same database. The difference between the two is that MySQL-DS has JTA enabled while MySQL-DS-NonJTA does not. This is useful to separate operations during the database automated schema generation phase. Any change to a schema should be made outside the scope of JTA. Many JDBC drivers (for example) will fall apart (assorted type of SQLException) if you try to commit a connection with DDL and SQL mixed, or SQL first then DDL after. Consequently it is recommended to have a separate data source for such operations, hence using the non-jta-data-source.

In the drivers section, add:

```xml
<driver name="com.mysql" module="com.mysql">
  <xa-datasource-class>com.mysql.jdbc.jdbc2.optional.MysqlXADatasource</xa-datasource-class>
</driver>
```

The above defines which drivers to use for the data sources MySQL-DS and MySQL-DS-NonJTA.
Add DataNucleus to JBoss

This step adds the DataNucleus libraries as a JBoss module.

- Create a directory to store the DataNucleus libraries, as 
  $JBOSS_HOME/modules/org/datanucleus/main

- Add the following jars from the lib directory of the datanucleus-accessplatform-full-deps ZIP file 
  lib directory: datanucleus-api-jpa-XXX.jar, datanucleus-core-XXX.jar, datanucleus-rdbms-XXX.jar, datanucleus-jpa-query-XXX.jar

- Add a module.xml file in the $JBOSS_HOME/modules/org/datanucleus/main directory like this

```xml
<module xmlns="urn:jboss:module:1.1" name="org.datanucleus">
  <dependencies>
    <module name="javax.api"/>
    <module name="javax.persistence.api"/>
    <module name="javax.transaction.api"/>
    <module name="javax.validation.api"/>
  </dependencies>
  <resources>
    <resource-root path="datanucleus-api-jpa-5.0.0.release.jar"/>
    <resource-root path="datanucleus-core-5.0.0.release.jar"/>
    <resource-root path="datanucleus-rdbms-5.0.0.release.jar"/>
    <resource-root path="datanucleus-jpa-query-5.0.0.release.jar"/>
  </resources>
</module>
```

At this point, all the JPA dependencies are resolved.

A simple example using DataNucleus JPA and JBoss AS7

Now you simply need to define persistence.xml and use JPA as you normally would. In order to use DataNucleus as a persistence provider, the persistence.xml file must contain the "jboss.as.jpa.providerModule" property. Using the datasources defined above, an example of a persistence.xml file could be:

```xml
```
TomEE

Apache TomEE ships with OpenJPA/EclipseLink as the default JPA provider (depending on which version of TomEE), however any valid JPA provider can be used.

The basic steps are:

- Add the DataNucleus jars to `<tomee-home>/lib/`
- Configure the web-app or the server to use DataNucleus.

Webapp Configuration

Any web-app can specify the JPA provider it would like to use via the `persistence.xml` file, which can be at any of the following locations in a web-app

- `WEB-INF/persistence.xml` of the .war file
- `META-INF/persistence.xml` in any jar located in WEB-INF/lib/

A single web-app may have many `persistence.xml` files and each may use whichever JPA provider it needs. The following is an example of a fairly common `persistence.xml` for DataNucleus

```xml
<?xml version="1.0" encoding="UTF-8"?>
<persistence xmlns="http://java.sun.com/xml/ns/persistence" version="1.0">
  <persistence-unit name="[Persistence Unit Name]" transaction-type="JTA">
    <provider>org.datanucleus.api.jpa.PersistenceProviderImpl</provider>
    <!-- MySQL DS -->
    <jta-data-source>java:/jdbc/simple</jta-data-source>
    <non-jta-data-source>java:/jdbc/simple-nonjta</non-jta-data-source>

    <class>[Entities must be listed here]</class>

    <properties>
      <!-- Magic JBoss property for specifying the persistence provider -->
      <property name="jboss.as.jpa.providerModule" value="org.datanucleus"/>

      <!-- following is probably not useful... but it ensures we bind to the JTA transaction manager...-->
      <property name="datanucleus.jtaLocator" value="custom_jndi"/>
      <property name="datanucleus.jtaJndiLocation" value="java:/TransactionManager"/>

      <property name="datanucleus.autoCreateSchema" value="true"/>
      <property name="datanucleus.metadata.validate" value="false"/>
      <property name="datanucleus.validateTables" value="false"/>
      <property name="datanucleus.validateConstraints" value="false"/>
    </properties>
  </persistence-unit>
</persistence>
```
<persistence version="2.1" xmlns="http://xmlns.jcp.org/xml/ns/persistence"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://xmlns.jcp.org/xml/ns/persistence
http://xmlns.jcp.org/xml/ns/persistence/persistence_2_1.xsd">
    <persistence-unit name="movie-unit">
        <provider>org.datanucleus.api.jpa.PersistenceProviderImpl</provider>
        <jta-data-source>movieDatabase</jta-data-source>
        <non-jta-data-source>movieDatabaseUnmanaged</non-jta-data-source>
        <properties>
            <property name="javax.persistence.schema-generation.database.action"
                value="drop-and-create"/>
        </properties>
    </persistence-unit>
</persistence>

Note that you may have to set the persistence property <code>datanucleus.jtaLocator</code> and <code>datanucleus.jtaJndiLocation</code> to find your JTA "TransactionManager". See the <code>persistence</code> properties for details of those.

### Server Configuration

The default JPA provider can be changed at the server level to favour DataNucleus over OpenJPA/EclipseLink. Using the <code><tomee-home>/conf/system.properties</code> file or any other valid means of setting java.lang.System.getProperties(), the following standard properties can set the default for any persistence.xml file.

```java
javax.persistence.provider
javax.persistence.transactionType
javax.persistence.jtaDataSource
javax.persistence.nonJtaDataSource
```

So, for example, DataNucleus can become the default provider via setting

```
CATALINA_OPTS=-
Djavax.persistence.provider=org.datanucleus.api.jpa.PersistenceProviderImpl
```

You must of course add the DataNucleus libraries to <code><tomee-home>/lib/</code> for this to work.

### DataNucleus libraries

Jars needed for DataNucleus 5.1:
# Add:
<tomee-home>/lib/datanucleus-core-5.1.0-m1.jar
<tomee-home>/lib/datanucleus-api-jpa-5.1.0-m1.jar
<tomee-home>/lib/datanucleus-rdbms-5.1.0-m1.jar

# Remove (optional):
<tomee-home>/lib/asm-3.2.jar
<tomee-home>/lib/commons-lang-2.6.jar
<tomee-home>/lib/openjpa-2.2.0.jar (or EclipseLink)
<tomee-home>/lib/serp-1.13.1.jar
**OSGi Environments**

DataNucleus jars are OSGi bundles, and as such, can be deployed in an OSGi environment. Being an OSGi environment care must be taken with respect to class-loading. In particular the persistence property `datanucleus.primaryClassLoader` will need setting.

An important thing to note: any dependent jar that is required by DataNucleus needs to be OSGi enabled. By this we mean the jar needs to have the MANIFEST.MF file including `ExportPackage` for the packages required by DataNucleus. Failure to have this will result in `ClassNotFoundException` when trying to load its classes.

The `javax.persistence` jar that is included in the DataNucleus distribution is OSGi-enabled.

When using DataNucleus in an OSGi environment you can set the persistence property `datanucleus.plugin.pluginRegistryClassName` to `org.datanucleus.plugin.OSGiPluginRegistry`.

**JPA and OSGi**

In a non OSGi world the persistence provider implementation is loaded using the service provider pattern. The full qualified name of the implementation is stored in a file under `META-INF/services/javax.persistence.spi.PersistenceProvider` (inside the jar of the implementation) and each time the persistence provider is required it gets loaded with a `Class.forName` using the name of the implementing class found inside the `META-INF/services/javax.persistence.spi.PersistenceProvider`. In the OSGi world that doesn’t work. The bundle that needs to load the persistence provider implementation cannot load `META-INF/services/javax.persistence.spi.PersistenceProvider`. A work around is to copy that file inside each bundle that requires access to the persistence provider. Another work around is to export the persistence provider as OSGi service. This is what the DataNucleus JPA jar does.

Further reading available on [this link](#).

**Sample using OSGi and JPA**

Please make use of the OSGi sample. This provides a simple example that you can build and load into such as Apache Karaf to demonstrate JPA persistence. Here we attempt to highlight the key aspects specific to OSGi in this sample.

Model classes are written in the exact same way as you would for any application.

Creation of the EMF is specified in a persistence-unit as normal except that we need to provide two overriding properties

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so we have provided a class loader for the OSGi context of the application, and also specified that we want to use the OSGiPluginRegistry.

All persistence and query operations using EntityManager etc thereafter are identical to what you would use in a normal JavaSE/JavaEE application.

The pom.xml also defines the imports/exports for our OSGi application bundle, so look at this if wanting guidance on what these could look like when using Maven and the “felix bundle” plugin.

If you read the file README.txt you can see basic instructions on how to deploy this application into a fresh download of Apache Karaf, and run it. It makes uses of Spring DM to start the JPA "application".

**LocalContainerEntityManagerFactoryBean class for use in Virgo 3.0 OSGi environment**

When using DataNucleus 3.x in a Virgo 3.0.x OSGi environment, which is essentially Eclipse Equinox + Spring dm Server with Spring 3.0.5.RELEASE included, the following class is working for me to use in your Spring configuration. You can use this class as a drop-in replacement for Spring's org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean. It was inspired by the code-ish sample at HOWTO Use Datanucleus with OSGi and Spring DM.

```java
import java.util.HashMap;
import java.util.Map;
import javax.persistence.EntityManagerFactory;
import javax.persistence.PersistenceException;
import javax.persistence.spi.PersistenceUnitInfo;
import org.datanucleus.util.StringUtils;
import org.osgi.framework.Bundle;
import org.osgi.framework.BundleContext;
import org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean;
import org.springframework.osgi.context.BundleContextAware;

public class DataNucleusOsgiLocalContainerEntityManagerFactoryBean extends LocalContainerEntityManagerFactoryBean implements BundleContextAware {
    
    public static final String DEFAULT_JPA_API_BUNDLE_SYMBOLIC_NAME =
```
public static final String DEFAULT_PERSISTENCE_PROVIDER_CLASS_NAME = "org.datanucleus.api.jpa.PersistenceProviderImpl";

public static final String DEFAULT_OSGI_PLUGIN_REGISTRAR_CLASS_NAME = "org.datanucleus.plugin.OSGiPluginRegistry";
public static final String DEFAULT_OSGI_PLUGIN_REGISTRAR_PROPERTY_NAME = "datanucleus.plugin.pluginRegistryClassName";

protected BundleContext bundleContext;
protected ClassLoader classLoader;

protected String jpaApiBundleSymbolicName = DEFAULT_JPA_API_BUNDLE_SYMBOLIC_NAME;
protected String persistenceProviderClassName = DEFAULT_PERSISTENCE_PROVIDER_CLASS_NAME;
protected String osgiPluginRegistrarClassName = DEFAULT_OSGI_PLUGIN_REGISTRAR_CLASS_NAME;
protected String osgiPluginRegistrarPropertyName = DEFAULT_OSGI_PLUGIN_REGISTRAR_PROPERTY_NAME;

@Override
public void setBundleContext(BundleContext bundleContext) {
    this.bundleContext = bundleContext;
}

@Override
protected EntityManagerFactory createNativeEntityManagerFactory() throws PersistenceException
{
    ClassLoader original = getBeanClassLoader(); // save for later
    try
    {
        if (bundleContext != null)
        {
            // default
            String name = getPersistenceProviderClassName();
            PersistenceUnitInfo info = getPersistenceUnitInfo();
            if (info != null && !StringUtils.isEmpty(info.getPersistenceProviderClassName()))
            {
                // use class name of PU
                name = info.getPersistenceProviderClassName();
            }

            if (StringUtils.isEmpty(getJpaApiBundleSymbolicName()))
            {
                throw new IllegalStateException("no DataNucleus JPA API bundle symbolic name given");
            }

            // set the bean class loader to use it so that Spring can find the
persistence provider class

```java
setBeanClassLoader(getBundleClassLoader(getJpaApiBundleSymbolicName(), name));

// since we're in an OSGi environment by virtue of the use of this
class, ensure a plugin registration mechanism is being used
if (info == null || (info.getProperties() != null && !info.getProperties().containsKey(getOsgiPluginRegistrarPropertyName())))
{
    Map<String, Object> map = getJpaPropertyMap();
    map = map == null ? new HashMap<String, Object>() : map;
    if (map.get(getOsgiPluginRegistrarPropertyName()) == null) {
        map.put(getOsgiPluginRegistrarPropertyName(),
        getOsgiPluginRegistrarClassName());
    }
}

// now let Springy do its thingy
return super.createNativeEntityManagerFactory();
}
finally
{
    setBeanClassLoader(original); // revert bean classloader
}

protected ClassLoader getBundleClassLoader(String bundleSymbolicName,String classNameToLoad)
{
    ClassLoader classloader = null;
    Bundle[] bundles = bundleContext.getBundles();
    for (int x = 0; x < bundles.length; x++)
    {
        if (bundleSymbolicName.equals(bundles[x].getSymbolicName())) {
            try {
                classloader = bundles[x].loadClass(classNameToLoad).
                getClassLoader();
            } catch (ClassNotFoundException e) {
                e.printStackTrace();
            } catch (BrokenProcessGroupException e) {
                e.printStackTrace();
            } catch (Exception e) {
                e.printStackTrace();
            }
            break;
        }
    }
    return classloader;
}

public String getJpaApiBundleSymbolicName() {

return jpaApiBundleSymbolicName;
}

public void setJpaApiBundleSymbolicName(String jpaApiBundleSymbolicName) {
    this.jpaApiBundleSymbolicName = jpaApiBundleSymbolicName;
}

public String getPersistenceProviderClassName() {
    return persistenceProviderClassName;
}

public void setPersistenceProviderClassName(String persistenceProviderClassName) {
    this.persistenceProviderClassName = persistenceProviderClassName;
}

public String getOsgiPluginRegistrarClassName() {
    return osgiPluginRegistrarClassName;
}

public void setOsgiPluginRegistrarClassName(String osgiPluginRegistrarClassName) {
    this.osgiPluginRegistrarClassName = osgiPluginRegistrarClassName;
}

public String getOsgiPluginRegistrarPropertyName() {
    return osgiPluginRegistrarPropertyName;
}

public void setOsgiPluginRegistrarPropertyName(String osgiPluginRegistrarPropertyName) {
    this.osgiPluginRegistrarPropertyName = osgiPluginRegistrarPropertyName;
}
Performance Tuning

DataNucleus, by default, provides certain functionality. In particular circumstances some of this functionality may not be appropriate and it may be desirable to turn on or off particular features to gain more performance for the application in question. This section contains a few common tips

Enhancement

You should perform enhancement before runtime. That is, do not use java agent since it will enhance classes at runtime, when you want responsiveness from your application.

Schema

JPA provides properties for generating the schema at startup, and DataNucleus also provides some of its own (datanucleus.schema.autoCreateAll, datanucleus.schema.autoCreateTables, datanucleus.schema.autoCreateColumns, and datanucleus.schema.autoCreateConstraints). This can cause performance issues at startup. We recommend setting these to false at runtime, and instead using SchemaTool to generate any required database schema before running DataNucleus (for RDBMS, HBase, etc).

Where you have an inheritance tree it is best to add a discriminator to the base class so that it's simple for DataNucleus to determine the class name for a particular row. For RDBMS: this results in cleaner/simpler SQL which is faster to execute, otherwise it would be necessary to do a UNION of all possible tables. For other datastores, a discriminator stores the key information necessary to instantiate the resultant class on retrieval so ought to be more efficient also.

DataNucleus provides 3 persistence properties (datanucleus.schema.validateTables, datanucleus.schema.validateConstraints, datanucleus.schema.validateColumns) that enforce strict validation of the datastore tables against the Meta-Data defined tables. This can cause performance issues at startup. In general this should be run only at schema generation, and should be turned off for production usage. Set all of these properties to false. In addition there is a property datanucleus.rdbms.CheckExistTablesOrViews which checks whether the tables/views that the classes map onto are present in the datastore. This should be set to false if you require fast start-up.

Finally, the property datanucleus.rdbms.initializeColumnInfo determines whether the default values for columns are loaded from the database. This property should be set to NONE to avoid loading database metadata.

To sum up, the optimal settings with schema creation and validation disabled are:
#schema creation

datanucleus.schema.autoCreateAll=false
datanucleus.schema.autoCreateTables=false
datanucleus.schema.autoCreateColumns=false
datanucleus.schema.autoCreateConstraints=false

#schema validation

datanucleus.schema.validateTables=false
datanucleus.schema.validateConstraints=false
datanucleus.schema.validateColumns=false
datanucleus.rdbms.CheckExistTablesOrViews=false
datanucleus.rdbms.initializeColumnInfo=None

## EntityManagerFactory usage

Creation of **EntityManagerFactory** objects can be expensive and should be kept to a minimum. Depending on the structure of your application, use a single factory per datastore wherever possible. Clearly if your application spans multiple servers then this may be impractical, but should be borne in mind.

You can improve startup speed by not specifying all classes in the *persistence-unit* so that they are discovered at runtime. Obviously this may impact on persistence operations later if classes are not known about.

Some RDBMS (such as Oracle) have trouble returning information across multiple catalogs/schemas and so, when DataNucleus starts up and tries to obtain information about the existing tables, it can take some time. This is easily remedied by specifying the catalog/schema name to be used - either for the EMF as a whole (using the persistence properties **datanucleus.Catalog**, **datanucleus.Schema**, or using the settings in *persistence.xml*), or for the package/class using attributes in the MetaData. This subsequently reduces the amount of information that the RDBMS needs to search through and so can give significant speed ups when you have many catalogs/schemas being managed by the RDBMS.

## EntityManager usage

Clearly the structure of your application will have a major influence on how you utilise an **EntityManager**. A pattern that gives a clean definition of process is to use a different persistence manager for each request to the data access layer. This reduces the risk of conflicts where one thread performs an operation and this impacts on the successful completion of an operation being performed by another thread. Creation of EM’s is not an expensive process and use of multiple threads writing to the same manager should be avoided.

**Make sure that you always close the EntityManager after use.** It releases all resources connected to it, and failure to do so will result in memory leaks. Also note that when closing the EntityManager if you have the persistence property **datanucleus.detachOnClose** set to *true* (when in an extended PersistenceContext) this will detach all objects in the Level1 cache. Disable this if you don’t need these objects to be detached, since it can be expensive when there are many objects.
Persistence Process

To optimise the persistence process for performance you need to analyse what operations are performed and when, to see if there are some features that you could disable to get the persistence you require and omit what is not required. If you think of a typical transaction, the following describes the process

- Start the transaction
- Perform persistence operations. If you are using "optimistic" transactions then all datastore operations will be delayed until commit. Otherwise all datastore operations will default to being performed immediately. If you are handling a very large number of objects in the transaction you would benefit by either disabling "optimistic" transactions, or alternatively setting the persistence property `datanucleus.flush.mode` to `AUTO`, or alternatively, do a manual flush every "n" objects, like this

```java
for (int i=0;i<1000000;i++)
{
    if ((i%10000)/10000 == 0 && i != 0)
    {
        pm.flush();
    }
...
}
```
- Commit the transaction
  - All dirty objects are flushed.
  - Objects enlisted in the transaction are put in the Level 2 cache. You can disable the level 2 cache with the persistence property `datanucleus.cache.level2.type` set to `none`
  - Objects enlisted in the transaction are detached if you have the persistence property `datanucleus.detachAllOnCommit` set to `true` (when using a transactional PersistenceContext). Disable this if you don't need these objects to be detached at this point

Database Connection Pooling

DataNucleus, by default, will allocate connections when they are required. It then will close the connection.

In addition, when it needs to perform something via JDBC (RDBMS datastores) it will allocate a PreparedStatement, and then discard the statement after use. This can be inefficient relative to a database connection and statement pooling facility such as Apache DBCP. With Apache DBCP a Connection is allocated when required and then when it is closed the Connection isn't actually closed but just saved in a pool for the next request that comes in for a Connection. This saves the time taken to establish a Connection and hence can give performance speed ups the order of maybe 30% or more. You can read about how to enable connection pooling with DataNucleus in the Connection Pooling Guide.
As an addendum to the above, you could also turn on caching of PreparedStatements. This can also give a performance boost, depending on your persistence code, the JDBC driver and the SQL being issued. Look at the persistence property `datanucleus.connectionPool.maxStatements`.

### Retrieval of object by identity

If you are retrieving an object by its identity and know that it will be present in the Level2 cache, for example, you can set the persistence property `datanucleus.findObject.validateWhenCached` to `false` and this will skip a separate call to the datastore to validate that the object exists in the datastore.

### Value Generators

DataNucleus provides a series of value generators for generation of identity values. These can have an impact on the performance depending on the choice of generator, and also on the configuration of the generator.

- The `max` strategy should not really be used for production since it makes a separate DB call for each insertion of an object. Something like the `TABLE` strategy should be used instead. Better still would be to choose `AUTO` and let DataNucleus decide for you.

- The `SEQUENCE` strategy allows configuration of the datastore sequence. The default can be non-optimum. As a guide, you can try setting `key-cache-size` to `10`

The `AUTO` identity generator value is the recommended choice since this will allow DataNucleus to decide which identity generator is best for the datastore in use.

### Collection/Map caching

DataNucleus has 2 ways of handling calls to SCO Collections/Maps. The original method was to pass all calls through to the datastore. The second method (which is now the default) is to cache the collection/map elements/keys/values. This second method will read the elements/keys/values once only and thereafter use the internally cached values. This second method gives significant performance gains relative to the original method. You can configure the handling of collections/maps as follows:-

- **Globally for the EMF** - this is controlled by setting the persistence property `datanucleus.cache.collections`. Set it to `true` for caching the collections (default), and `false` to pass through to the datastore.

- **For the specific Collection/Map** - this overrides the global setting and is controlled by adding a MetaData `<collection>` or `<map>` extension `cache`. Set it to `true` to cache the collection data, and `false` to pass through to the datastore.

The second method also allows a finer degree of control. This allows the use of lazy loading of data, hence elements will only be loaded if they are needed. You can configure this as follows:-
• Globally for the EMF - this is controlled by setting the property `datanucleus.cache.collections.lazy`. Set it to true to use lazy loading, and set it to false to load the elements when the collection/map is initialised.

• For the specific Collection/Map - this overrides the global EMF setting and is controlled by adding a MetaData `<collection>` or `<map>` extension `cache-lazy-loading`. Set it to `true` to use lazy loading, and `false` to load once at initialisation.

NonTransactional Reads (Reading persistent objects outside a transaction)

Performing non-transactional reads has advantages and disadvantages in performance and data freshness in cache. The objects read are held cached by the EntityManager. The second time an application requests the same objects from the EntityManager they are retrieved from cache. The time spent reading the object from cache is minimum, but the objects may become stale and not represent the database status. If fresh values need to be loaded from the database, then the user application should first call `refresh` on the object.

Another disadvantage of performing non-transactional reads is that each operation realized opens a new database connection, but it can be minimized with the use of connection pools, and also on some of the datastore the (nontransactional) connection is retained.

Accessing fields of persistent objects when not managed by a EntityManager

Reading fields of unmanaged objects (outside the scope of an `EntityManager`) is a trivial task, but performed in a certain manner can determine the application performance. The objective here is not give you an absolute response on the subject, but point out the benefits and drawbacks for the many possible solutions.

• Use `datanucleus.RetainValues=true`. This is the default for JPA operation and will ensure that after commit the fields of the object retain their values (rather than being nulled).

• Use `detach` method.
Object copy = null;
try {
    EntityManager em = emf.createEntityManager();
    em.getTransaction().begin();

    //retrieve in some way the object, query, find, etc
    Object obj = em.find(MyClass.class, id);
    copy = em.detach(obj);

    em.getTransaction().commit();
}
finally {
    em.close();
}
//read or change the detached object here
System.out.println(copy.getName());

- Use datanucleus.detachAllOnCommit=true. Dependent on the persistence context you may automatically have this set.

Object obj = null;
try {
    EntityManager pm = emf.createEntityManager();
    em.getTransaction().begin();

    //retrieve in some way the object, query, find, etc
    obj = em.find(MyClass.class, id);
    em.getTransaction().commit(); // Object "obj" is now detached
}
finally {
    em.close();
}
//read or change the detached object here
System.out.println(obj.getName());

The bottom line is to not use detachment if instances will only be used to read values.

**Fetch Control**

When fetching objects you have control over what gets fetched. This can have an impact if you are then detaching those objects. With JPA the maximum fetch depth is -1 (unlimited). So with JPA you ought to set it to the extent that you want to detach, or better still make use of JPA Entity Graphs to control the specific fields to detach.
Logging

I/O consumes a huge slice of the total processing time. Therefore it is recommended to reduce or disable logging in production. To disable the logging set the DataNucleus category to OFF in the Log4j configuration. See Logging for more information.

```
log4j.category.DataNucleus=OFF
```

General Comments

In most applications, the performance of the persistence layer is very unlikely to be a bottleneck. More likely the design of the datastore itself, and in particular its indices are more likely to have the most impact, or alternatively network latency. That said, it is the DataNucleus projects' committed aim to provide the best performance possible, though we also want to provide functionality, so there is a compromise with respect to resource.

A benchmark is defined as "a series of persistence operations performing particular things e.g persist \( n \) objects, or retrieve \( n \) objects". If those operations are representative of your application then the benchmark is valid to you.

To find (or create) a benchmark appropriate to your project you need to determine the typical persistence operations that your application will perform. Are you interested in persisting 100 objects at once, or 1 million, for example? Then when you have a benchmark appropriate for that operation, compare the persistence solutions.

The performance tuning guide above gives a good oversight of tuning capabilities, and also refer to the following blog entry for our take on performance of DataNucleus AccessPlatform. And then the later blog entry about how to tune for bulk operations

GeeCon JPA provider comparison (Jun 2012)

There is an interesting presentation on JPA provider performance that was presented at GeeCon 2012 by Patrycja Wegrzynowicz. This presentation takes the time to look at what operations the persistence provider is performing, and does more than just "persist large number of flat objects into a single table", and so gives you something more interesting to analyse. DataNucleus comes out pretty well in many situations. You can also see the PDF here.

PolePosition (Dec 2008)

The PolePosition benchmark is a project on SourceForge to provide a benchmark of the write, read and delete of different data structures using the various persistence tools on the market. JPOX (DataNucleus predecessor) was run against this benchmark just before being renamed as DataNucleus and the following conclusions about the benchmark were made.

- It is essential that tests for such as Hibernate and DataNucleus performance comparable things. Some of the original tests had the "delete" simply doing a "DELETE FROM TBL" for Hibernate yet doing an Extent followed by delete each object individually for a JDO implementation. This is
unfair comparison and in the source tree in JPOX SVN this is corrected. This fix was pointed out to the PolePos SourceForge project but is not, as yet, fixed

• It is essential that schema is generated before the test, otherwise the test is no longer a benchmark of just a persistence operation. The source tree in JPOX SVN assumes the schema exists. This fix was pointed out to the PolePos SourceForge project but is not, as yet, fixed

• Each persistence implementation should have its own tuning options, and be able to add things like discriminators since that is what would happen in a real application. The source tree in JPOX SVN does this for JPOX running. Similarly a JDO implementation would tune the entity graphs being used - this is not present in the SourceForge project but is in JPOX SVN.

• DataNucleus performance is considered to be significantly improved over JPOX particularly due to batched inserts, and due to a rewritten query implementation that does enhanced fetching.
Monitoring

DataNucleus allows a user to enable various MBeans internally. These can then be used for monitoring the number of datastore calls etc.

Via API

The simplest way to monitor DataNucleus is to use its API for monitoring. Internally there are several MBeans (as used by JMX) and you can navigate to these to get the required information. To enable this set the persistence property `datanucleus.enableStatistics` to `true`. There are then two sets of statistics; one for the EMF and one for each EM. You access these as follows

```java
JPAEntityManagerFactory dnEMF = (JPAEntityManagerFactory)emf;
FactoryStatistics stats = dnEMF.getNucleusContext().getStatistics();
... (access the statistics information)

JPAEntityManager dnEM = (JPAEntityManager)em;
ManagerStatistics stats = dnEM.getExecutionContext().getStatistics();
... (access the statistics information)
```

Using JMX

The MBeans used by DataNucleus can be accessed via JMX at runtime. More about JMX [here](#).

An MBean server is bundled with Sun/Oracle JRE since version 1.5, and you can easily activate DataNucleus MBeans registration by creating your EMF with the persistence property `datanucleus.jmxType` as `default`

Additionally, setting a few system properties are necessary for configuring the Sun JMX implementation. The minimum properties required are the following:

- `com.sun.management.jmxremote`
- `com.sun.management.jmxremote.authenticate`
- `com.sun.management.jmxremote.ssl`
- `com.sun.management.jmxremote.port=<port number>`

Usage example:

```
java -cp TheClassPathInHere
    -Dcom.sun.management.jmxremote
    -Dcom.sun.management.jmxremote.authenticate=false
    -Dcom.sun.management.jmxremote.ssl=false
    -Dcom.sun.management.jmxremote.port=8001
    TheMainClassInHere
```
Once you start your application and DataNucleus is initialized you can browse DataNucleus MBeans using a tool called jconsole (jconsole is distributed with the Sun JDK) via the URL:

```
service:jmx:rmi:///jndi/rmi://hostName:portNum/jmxrmi
```

Note that the mode of usage is presented in this document as matter of example, and by no means we recommend to disable authentication and secured communication channels. Further details on the Sun JMX implementation and how to configure it properly can be found [here](#).

DataNucleus MBeans are registered in a MBean Server when DataNucleus is started up (e.g. upon JPA EMF instantiation). To see the full list of DataNucleus MBeans, refer to the [javadocs](#).

mx4j

To enable management using MX4J you must specify the persistence property `datanucleus.jmxType` as `mx4j` when creating the EMF, and have the `mx4j` and `mx4j-tools` jars in the CLASSPATH.
Many applications make use of multiple datastores. It is a common requirement to be able to replicate parts of one datastore in another datastore. Obviously, depending on the datastore, you could make use of the datastores own capabilities for replication. DataNucleus provides its own extension to JPA to allow replication from one datastore to another. This extension doesn’t restrict you to using 2 datastores of the same type. You could replicate from RDBMS to XML for example, or from MySQL to HSQLDB.

You need to make sure you have the persistence property `datanucleus.attachSameDatastore` set to `false` if using replication.

Note that the case of replication between two RDBMS of the same type is usually way more efficiently replicated using the capabilities of the datastore itself.

The following sample code will replicate all objects of type `Product` and `Employee` from EMF1 to EMF2. These EMFs are created in the normal way so, as mentioned above, EMF1 could be for a MySQL datastore, and EMF2 for XML. By default this will replicate the complete object graphs reachable from these specified types.

```java
import org.datanucleus.api.jpa.JPAReplicationManager;

...

JPAReplicationManager replicator = new JPAReplicationManager(emf1, emf2);
replicator.replicate(new Class[]{Product.class, Employee.class});
```
DataNucleus Logging

DataNucleus can be configured to log significant amounts of information regarding its process. This information can be very useful in tracking the persistence process, and particularly if you have problems. DataNucleus will log as follows:

- **Log4J** - if you have Log4J in the CLASSPATH, Apache Log4J will be used
- **java.util.logging** - if you don’t have Log4J in the CLASSPATH, then *java.util.logging* will be used

DataNucleus logs messages to various categories (in Log4J and java.util.logging these correspond to a "Logger"), allowing you to filter the logged messages by these categories - so if you are only interested in a particular category you can effectively turn the others off. DataNucleus’s log is written by default in English. If your JRE is running in a Spanish locale then your log will be written in Spanish.

If you have time to translate our log messages into other languages, please contact one of the developers via Groups.IO or Gitter.

Logging Categories

DataNucleus uses a series of **categories**, and logs all messages to these **categories**. Currently DataNucleus uses the following:

- **DataNucleus.Persistence** - All messages relating to the persistence process
- **DataNucleus.Transaction** - All messages relating to transactions
- **DataNucleus.Connection** - All messages relating to Connections.
- **DataNucleus.Query** - All messages relating to queries
- **DataNucleus.Cache** - All messages relating to the DataNucleus Cache
- **DataNucleus.MetaData** - All messages relating to MetaData
- **DataNucleus.Datastore** - All general datastore messages
- **DataNucleus.Datastore.Schema** - All schema related datastore log messages
- **DataNucleus.DatastorePersist** - All datastore persistence messages
- **DataNucleus.Datastore.Retrieve** - All datastore retrieval messages
- **DataNucleus.Datastore.Native** - Log of all 'native' statements sent to the datastore
- **DataNucleus.General** - All general operational messages
- **DataNucleus.Lifecycle** - All messages relating to object lifecycle changes
- **DataNucleus.ValueGeneration** - All messages relating to value generation
- **DataNucleus.Enhancer** - All messages from the DataNucleus Enhancer.
- **DataNucleus.SchemaTool** - All messages from DataNucleus SchemaTool
- **DataNucleus.JDO** - All messages general to JDO
- **DataNucleus.JPA** - All messages general to JPA
Using Log4J

Log4J allows logging messages at various severity levels. The levels used by Log4J, and by DataNucleus's use of Log4J are **DEBUG, INFO, WARN, ERROR, FATAL**. Each message is logged at a particular level to a category (as described above). The other setting is **OFF** which turns off a logging category; very useful in a production situation where maximum performance is required.

To enable the DataNucleus log, you need to provide a Log4J configuration file when starting up your application. This may be done for you if you are running within a JavaEE application server (check your manual for details). If you are starting your application yourself, you would set a JVM parameter as

```
-Dlog4j.configuration=file:log4j.properties
```

where **log4j.properties** is the name of your Log4J configuration file. Please note the **file:** prefix to the file since a URL is expected.

The Log4J configuration file is very simple in nature, and you typically define where the log goes to (e.g. to a file), and which logging level messages you want to see. Here's an example

```
# Define the destination and format of our logging
log4j.appender.A1.File=datanucleus.log
log4j.appender.A1.layout.ConversionPattern=%d{HH:mm:ss,SSS} (%t) %-5p [%c] - %m%n

# DataNucleus Categories
log4j.category.DataNucleus.JDO=INFO, A1
log4j.category.DataNucleus.Cache=INFO, A1
log4j.category.DataNucleus.MetaData=INFO, A1
log4j.category.DataNucleus.General=INFO, A1
log4j.category.DataNucleus.Transaction=INFO, A1
log4j.category.DataNucleus.Datastore=DEBUG, A1
log4j.category.DataNucleus.ValueGeneration=DEBUG, A1
log4j.category.DataNucleus.Enhancer=INFO, A1
log4j.category.DataNucleus.SchemaTool=INFO, A1
```

In this example, I am directing my log to a file (**datanucleus.log**). I have defined a particular "pattern" for the messages that appear in the log (to contain the date, level, category, and the message itself). In addition I have assigned a level "threshold" for each of the DataNucleus categories. So in this case I want to see all messages down to DEBUG level for the DataNucleus RDBMS persister.
Turning OFF the logging, or at least down to ERROR level provides a significant improvement in performance. With Log4J you do this via

```
log4j.category.DataNucleus=OFF
```

### Using java.util.logging

`java.util.logging` allows logging messages at various severity levels. The levels used by java.util.logging, and by DataNucleus's internally are `fine, info, warn, severe`. Each message is logged at a particular level to a category (as described above).

By default, the `java.util.logging` configuration is taken from a properties file `<JRE_DIRECTORY>/lib/logging.properties`. Modify this file and configure the categories to be logged, or use the `java.util.logging.config.file` system property to specify a properties file (in java.util.Properties format) where the logging configuration will be read from. Here is an example:

```
handlers=java.util.logging.FileHandler, java.util.logging.ConsoleHandler
DataNucleus.General.level=fine
DataNucleus.JDO.level=fine

# --- ConsoleHandler ---
# Override of global logging level
java.util.logging.ConsoleHandler.level=SEVERE
java.util.logging.ConsoleHandler.formatter=java.util.logging.SimpleFormatter

# --- FileHandler ---
# Override of global logging level
java.util.logging.FileHandler.level=SEVERE

# Naming style for the output file:
java.util.logging.FileHandler.pattern=datanucleus.log

# Limiting size of output file in bytes:
java.util.logging.FileHandler.limit=50000

# Number of output files to cycle through, by appending an integer to the base file name:
java.util.logging.FileHandler.count=1

# Style of output (Simple or XML):
java.util.logging.FileHandler.formatter=java.util.logging.SimpleFormatter
```

Please read the [javadocs](https://docs.oracle.com/javase/8/docs/api/) for `java.util.logging` for additional details on its configuration.
Sample Log Output

Here is a sample of the type of information you may see in the DataNucleus log when using Log4J.

```
21:26:09,000 (main) INFO  DataNucleus.Datastore.Schema - Adapter initialised: MySQLAdapter, MySQL version 4.0.11
21:26:09,370 (main) DEBUG DataNucleus.Datastore.Schema - CREATE TABLE null.DELETE_ME1080077169045
(    UNUSED INTEGER NOT NULL ) TYPE=INNODB
21:26:09,375 (main) DEBUG DataNucleus.Datastore.Schema - Execution Time = 3 ms
21:26:09,388 (main) WARN  DataNucleus.Datastore.Schema - Schema Name could not be determined for this datastore
21:26:09,388 (main) DEBUG DataNucleus.Datastore.Schema - DROP TABLE DELETE_ME1080077169045
21:26:09,392 (main) DEBUG DataNucleus.Datastore.Schema - Execution Time = 3 ms
(    CLASS_NAME VARCHAR (128) NOT NULL UNIQUE ,    `TABLE_NAME` VARCHAR (127) NOT NULL UNIQUE ) TYPE=INNODB
21:26:09,416 (main) DEBUG DataNucleus.Datastore.Schema - Execution Time = 10 ms
21:26:09,417 (main) DEBUG DataNucleus.Datastore - Retrieving type for table DataNucleus_TABLES
21:26:09,425 (main) DEBUG DataNucleus.Datastore - Execution Time = 7 ms
```

So you see the time of the log message, the level of the message (DEBUG, INFO, etc), the category (DataNucleus.Datastore, etc), and the message itself. For example, if I had set the DataNucleus.Datastore.Schema to DEBUG and all other categories to INFO I would see all DDL statements sent to the database and very little else.

**HOWTO : Log with log4j and DataNucleus under OSGi**

This guide was provided by Marco Lopes, when using DataNucleus v2.2. All of the bundles which use
log4j should have `org.apache.log4j` in their Import-Package attribute! (use: `org.apache.log4j;resolution:=optional` if you don’t want to be stuck with log4j whenever you use an edited bundle in your project!).

**Method 1**

- Create a new ”Fragment Project”. Call it whatever you want (ex: log4j-fragment)
- You have to define a “Plugin-ID”, that’s the plugin where DN will run
- Edit the MANIFEST
- Under RUNTIME add log4j JAR to the Classpath
- Under Export-Packages add org.apache.log4j
- Save MANIFEST
- PASTE the log4j PROPERTIES file into the SRC FOLDER of the Project

**Method 2**

- Get an ”OSGI Compliant” log4j bundle (you can get it from the SpringSource Enterprise Bundle Repository
- Open the Bundle JAR with WINRAR (others might work)
- PASTE the log4j PROPERTIES file into the ROOT of the bundle
- Exit. Winrar will ask to UPDATE the JAR. Say YES.
- Add the updated OSGI compliant Log4j bundle to your Plugin Project Dependencies (Required-Plugins)

Each method has it’s own advantages. Use method 1 if you need to EDIT the log4j properties file ON-THE-RUN. The disadvantage: it can only ”target” one project at a time (but very easy to edit the MANIFEST and select a new Host Plugin!). Use method 2 if you want to have log4j support in every project with only one file. The disadvantage: it’s not very practical to edit the log4j PROPERTIES file (not because of the bundle EDIT, but because you have to restart eclipse in order for the new bundle to be recognized).