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Datatypes In SQLite Version 3

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1. Datatypes In SQLite

Most SQL database engines (every SQL database engine other than SQLite, as far as we know) uses static, rigid typing. With static typing, the datatype of a value is determined by its container - the particular column in which the value is stored.

SQLite uses a more general dynamic type system. In SQLite, the datatype of a value is associated with the value itself, not with its container. The dynamic type system of SQLite is backwards compatible with the more common static type systems of other database engines in the sense that SQL statements that work on statically typed databases should work the same way in SQLite. However, the dynamic typing in SQLite allows it to do things which are not possible in traditional rigidly typed databases.

2. Storage Classes and Datatypes

Each value stored in an SQLite database (or manipulated by the database engine) has one of the following storage classes:

- **NULL.** The value is a NULL value.
- **INTEGER.** The value is a signed integer, stored in 1, 2, 3, 4, 6, or 8 bytes depending on the magnitude of the value.
- **REAL.** The value is a floating point value, stored as an 8-byte IEEE floating point number.
- **TEXT.** The value is a text string, stored using the database encoding (UTF-8, UTF-16BE or UTF-16LE).
- **BLOB.** The value is a blob of data, stored exactly as it was input.

A storage class is more general than a datatype. The INTEGER storage class, for example, includes 6 different integer datatypes of different lengths. This makes a difference on disk. But as soon as INTEGER values are read off of disk and into memory for processing, they are converted to the most general datatype (8-byte signed integer).

And so for the most part, "storage class" is indistinguishable from "datatype" and the two terms can be used interchangeably.

Any column in an SQLite version 3 database, except an [INTEGER PRIMARY KEY](#) column, may be used to store a value of any storage class.

All values in SQL statements, whether they are literals embedded in SQL statement text or [parameters](#) bound to [precompiled SQL statements](#) have an implicit storage class. Under circumstances described below, the database engine may convert values between numeric storage classes (INTEGER and REAL) and TEXT during query execution.

2.1. Boolean Datatype

SQLite does not have a separate Boolean storage class. Instead, Boolean values are stored as integers 0 (false) and 1 (true).

2.2. Date and Time Datatype

SQLite does not have a storage class set aside for storing dates and/or times. Instead, the built-in [Date And Time Functions](#) of SQLite are capable of storing dates and times as TEXT, REAL, or INTEGER values:

- **TEXT** as ISO8601 strings ("YYYY-MM-DD HH:MM:SS.SSS").
- **REAL** as Julian day numbers, the number of days since noon in Greenwich on November 24, 4714 B.C. according to the proleptic Gregorian calendar.
- **INTEGER** as Unix Time, the number of seconds since 1970-01-01 00:00:00 UTC.

Applications can chose to store dates and times in any of these formats and freely convert between formats using the built-in [date and time functions](#).

3. Type Affinity

SQL database engines that use rigid typing will usually try to automatically convert values to the appropriate datatype. Consider this:

```
CREATE TABLE t1(a INT, b VARCHAR(10));  
INSERT INTO t1(a,b) VALUES('123',456);
```

Rigidly-typed database will convert the string '123' into an integer 123 and the integer 456 into a string '456' prior to doing the insert.

In order to maximize compatibility between SQLite and other database engines, and so that the example above will work on SQLite as it does on other SQL database engines, SQLite supports the concept of "type affinity" on columns. The type affinity of a column is the recommended type for data stored in that column. The important idea here is that the type is recommended, not required. Any column can still store any type of data. It is just that some columns, given the choice, will prefer to use one storage class over another. The preferred storage class for a column is called its "affinity".

Each column in an SQLite 3 database is assigned one of the following type affinities:

- TEXT
- NUMERIC
- INTEGER
- REAL
- BLOB

(Historical note: The "BLOB" type affinity used to be called "NONE". But that term was easy to confuse with "no affinity" and so it was renamed.)

A column with TEXT affinity stores all data using storage classes NULL, TEXT or BLOB. If numerical data is inserted into a column with TEXT affinity it is converted into text form before being stored.

A column with NUMERIC affinity may contain values using all five storage classes. When text data is inserted into a NUMERIC column, the storage class of the text is converted to INTEGER or REAL (in order of preference) if the text is a well-formed integer or real literal, respectively. If the TEXT value is a well-formed integer literal that is too large to fit in a 64-bit signed integer, it is converted to REAL. For conversions between TEXT and REAL storage classes, only the first 15 significant decimal digits of the number are preserved. If the TEXT value is not a well-formed integer or real literal, then the value is stored as TEXT. For the purposes of this paragraph, hexadecimal integer literals are not considered well-formed and are stored as TEXT. (This is done for historical compatibility with versions of SQLite prior to [version 3.8.6](#) 2014-08-15 where hexadecimal integer literals were first introduced into SQLite.) No attempt is made to convert NULL or BLOB values.

A string might look like a floating-point literal with a decimal point and/or exponent notation but as long as the value can be expressed as an integer, the NUMERIC affinity will convert it into an integer. Hence, the string '3.0e+5' is stored in a column with NUMERIC affinity as the integer 300000, not as the floating point value 300000.0.

A column that uses INTEGER affinity behaves the same as a column with NUMERIC affinity. The difference between INTEGER and NUMERIC affinity is only evident in a [CAST expression](#).

A column with REAL affinity behaves like a column with NUMERIC affinity except that it forces integer values into floating point representation. (As an internal optimization, small floating point values with no fractional component and stored in columns with REAL affinity are written to disk as integers in order to take up less space and are automatically converted back into floating point as the value is read out. This optimization is completely invisible at the SQL level and can only be detected by examining the raw bits of the database file.)

A column with affinity BLOB does not prefer one storage class over another and no attempt is made to coerce data from one storage class into another.

3.1. Determination Of Column Affinity

The affinity of a column is determined by the declared type of the column, according to the following rules in the order shown:

1. If the declared type contains the string "INT" then it is assigned INTEGER affinity.

2. If the declared type of the column contains any of the strings "CHAR", "CLOB", or "TEXT" then that column has TEXT affinity. Notice that the type VARCHAR contains the string "CHAR" and is thus assigned TEXT affinity.
3. If the declared type for a column contains the string "BLOB" or if no type is specified then the column has affinity BLOB.
4. If the declared type for a column contains any of the strings "REAL", "FLOA", or "DOUB" then the column has REAL affinity.
5. Otherwise, the affinity is NUMERIC.

Note that the order of the rules for determining column affinity is important. A column whose declared type is "CHARINT" will match both rules 1 and 2 but the first rule takes precedence and so the column affinity will be INTEGER.

3.1.1. Affinity Name Examples

The following table shows how many common datatype names from more traditional SQL implementations are converted into affinities by the five rules of the previous section. This table shows only a small subset of the datatype names that SQLite will accept. Note that numeric arguments in parentheses that following the type name (ex: "VARCHAR(255)") are ignored by SQLite - SQLite does not impose any length restrictions (other than the large global [SQLITE_MAX_LENGTH](https://sqlite.org/datatype3.html) limit) on the length of strings, BLOBs or numeric values.

Example Typenames From The CREATE TABLE Statement or CAST Expression	Resulting Affinity	Rule Used To Determine Affinity
INT INTEGER TINYINT SMALLINT MEDIUMINT BIGINT UNSIGNED BIG INT INT2 INT8	INTEGER	1
CHARACTER(20) VARCHAR(255) VARYING CHARACTER(255) NCHAR(55) NATIVE CHARACTER(70) NVARCHAR(100) TEXT CLOB	TEXT	2
BLOB	BLOB	3

<i>no datatype specified</i>		
REAL DOUBLE DOUBLE PRECISION FLOAT	REAL	4
NUMERIC DECIMAL(10,5) BOOLEAN DATE DATETIME	NUMERIC	5

Note that a declared type of "FLOATING POINT" would give INTEGER affinity, not REAL affinity, due to the "INT" at the end of "POINT". And the declared type of "STRING" has an affinity of NUMERIC, not TEXT.

3.2. Affinity Of Expressions

Every table column has a type affinity (one of BLOB, TEXT, INTEGER, REAL, or NUMERIC) but expressions do not necessarily have an affinity.

Expression affinity is determined by the following rules:

- The right-hand operand of an IN or NOT IN operator has no affinity if the operand is a list and has the same affinity as the affinity of the result set expression if the operand is a SELECT.
- When an expression is a simple reference to a column of a real table (not a [VIEW](#) or subquery) then the expression has the same affinity as the table column.
 - Parentheses around the column name are ignored. Hence if X and Y.Z are column names, then (X) and (Y.Z) are also considered column names and have the affinity of the corresponding columns.
 - Any operators applied to column names, including the no-op unary "+" operator, convert the column name into an expression which always has no affinity. Hence even if X and Y.Z are column names, the expressions +X and +Y.Z are not column names and have no affinity.
- An expression of the form "CAST(expr AS type)" has an affinity that is the same as a column with a declared type of "type".
- A COLLATE operator has the same affinity as its left-hand side operand.
- Otherwise, an expression has no affinity.

3.3. Column Affinity For Views And Subqueries

The "columns" of a [VIEW](#) or FROM-clause subquery are really the expressions in the result set of the [SELECT](#) statement that implements the VIEW or subquery. Thus, the

affinity for columns of a VIEW or subquery are determined by the expression affinity rules above. Consider an example:

```
CREATE TABLE t1(a INT, b TEXT, c REAL);
CREATE VIEW v1(x,y,z) AS SELECT b, a+c, 42 FROM t1 WHERE b!=11;
```

The affinity of the v1.x column will be the same as the affinity of t1.b (TEXT), since v1.x maps directly into t1.b. But columns v1.y and v1.z both have no affinity, since those columns map into expression a+c and 42, and expressions always have no affinity.

When the [SELECT](#) statement that implements a [VIEW](#) or FROM-clause subquery is a [compound SELECT](#) then the affinity of each supposed column of the VIEW or subquery will be the affinity of the corresponding result column for one of the individual SELECT statements that make up the compound. However, it is indeterminate which of the SELECT statements will be used to determine affinity. Different constituent SELECT statements might be used to determine affinity at different times during query evaluation. Best practice is to avoid mixing affinities in a compound SELECT.

3.4. Column Affinity Behavior Example

The following SQL demonstrates how SQLite uses column affinity to do type conversions when values are inserted into a table.

```
CREATE TABLE t1(
  t TEXT,      -- text affinity by rule 2
  nu NUMERIC,  -- numeric affinity by rule 5
  i INTEGER,   -- integer affinity by rule 1
  r REAL,      -- real affinity by rule 4
  no BLOB      -- no affinity by rule 3
);

-- Values stored as TEXT, INTEGER, INTEGER, REAL, TEXT.
INSERT INTO t1 VALUES('500.0', '500.0', '500.0', '500.0', '500.0');
SELECT typeof(t), typeof(nu), typeof(i), typeof(r), typeof(no) FROM t1;
text|integer|integer|real|text

-- Values stored as TEXT, INTEGER, INTEGER, REAL, REAL.
DELETE FROM t1;
INSERT INTO t1 VALUES(500.0, 500.0, 500.0, 500.0, 500.0);
SELECT typeof(t), typeof(nu), typeof(i), typeof(r), typeof(no) FROM t1;
text|integer|integer|real|real

-- Values stored as TEXT, INTEGER, INTEGER, REAL, INTEGER.
DELETE FROM t1;
INSERT INTO t1 VALUES(500, 500, 500, 500, 500);
SELECT typeof(t), typeof(nu), typeof(i), typeof(r), typeof(no) FROM t1;
text|integer|integer|real|integer

-- BLOBs are always stored as BLOBs regardless of column affinity.
DELETE FROM t1;
INSERT INTO t1 VALUES(x'0500', x'0500', x'0500', x'0500', x'0500');
SELECT typeof(t), typeof(nu), typeof(i), typeof(r), typeof(no) FROM t1;
blob|blob|blob|blob|blob

-- NULLs are also unaffected by affinity
DELETE FROM t1;
INSERT INTO t1 VALUES(NULL,NULL,NULL,NULL,NULL);
SELECT typeof(t), typeof(nu), typeof(i), typeof(r), typeof(no) FROM t1;
null|null|null|null|null
```

4. Comparison Expressions

SQLite version 3 has the usual set of SQL comparison operators including "=", "==", "<", "<=", ">", ">=", "!=", "", "IN", "NOT IN", "BETWEEN", "IS", and "IS NOT", .

4.1. Sort Order

The results of a comparison depend on the storage classes of the operands, according to the following rules:

- A value with storage class NULL is considered less than any other value (including another value with storage class NULL).
- An INTEGER or REAL value is less than any TEXT or BLOB value. When an INTEGER or REAL is compared to another INTEGER or REAL, a numerical comparison is performed.
- A TEXT value is less than a BLOB value. When two TEXT values are compared an appropriate collating sequence is used to determine the result.
- When two BLOB values are compared, the result is determined using memcmp().

4.2. Type Conversions Prior To Comparison

SQLite may attempt to convert values between the storage classes INTEGER, REAL, and/or TEXT before performing a comparison. Whether or not any conversions are attempted before the comparison takes place depends on the type affinity of the operands.

To "apply affinity" means to convert an operand to a particular storage class if and only if the conversion does not lose essential information. Numeric values can always be converted into TEXT. TEXT values can be converted into numeric values if the text content is a well-formed integer or real literal, but not a hexadecimal integer literal. BLOB values are converted into TEXT values by simply interpreting the binary BLOB context as a text string in the current database encoding.

Affinity is applied to operands of a comparison operator prior to the comparison according to the following rules in the order shown:

- If one operand has INTEGER, REAL or NUMERIC affinity and the other operand has TEXT or BLOB or no affinity then NUMERIC affinity is applied to other operand.
- If one operand has TEXT affinity and the other has no affinity, then TEXT affinity is applied to the other operand.
- Otherwise, no affinity is applied and both operands are compared as is.

The expression "a BETWEEN b AND c" is treated as two separate binary comparisons "a >= b AND a <= c", even if that means different affinities are applied to 'a' in each of the comparisons. Datatype conversions in comparisons of the form "x IN (SELECT y ...)" are

handled is if the comparison were really "x=y". The expression "a IN (x, y, z, ...)" is equivalent to "a = +x OR a = +y OR a = +z OR ...". In other words, the values to the right of the IN operator (the "x", "y", and "z" values in this example) are considered to have no affinity, even if they happen to be column values or CAST expressions.

4.3. Comparison Example

```
CREATE TABLE t1(
  a TEXT,      -- text affinity
  b NUMERIC,   -- numeric affinity
  c BLOB,      -- no affinity
  d            -- no affinity
);

-- Values will be stored as TEXT, INTEGER, TEXT, and INTEGER respectively
INSERT INTO t1 VALUES('500', '500', '500', 500);
SELECT typeof(a), typeof(b), typeof(c), typeof(d) FROM t1;
text|integer|text|integer

-- Because column "a" has text affinity, numeric values on the
-- right-hand side of the comparisons are converted to text before
-- the comparison occurs.
SELECT a < 40,   a < 60,   a < 600 FROM t1;
0|1|1

-- Text affinity is applied to the right-hand operands but since
-- they are already TEXT this is a no-op; no conversions occur.
SELECT a < '40', a < '60', a < '600' FROM t1;
0|1|1

-- Column "b" has numeric affinity and so numeric affinity is applied
-- to the operands on the right. Since the operands are already numeric,
-- the application of affinity is a no-op; no conversions occur. All
-- values are compared numerically.
SELECT b < 40,   b < 60,   b < 600 FROM t1;
0|0|1

-- Numeric affinity is applied to operands on the right, converting them
-- from text to integers. Then a numeric comparison occurs.
SELECT b < '40', b < '60', b < '600' FROM t1;
0|0|1

-- No affinity conversions occur. Right-hand side values all have
-- storage class INTEGER which are always less than the TEXT values
-- on the left.
SELECT c < 40,   c < 60,   c < 600 FROM t1;
0|0|0

-- No affinity conversions occur. Values are compared as TEXT.
SELECT c < '40', c < '60', c < '600' FROM t1;
0|1|1

-- No affinity conversions occur. Right-hand side values all have
-- storage class INTEGER which compare numerically with the INTEGER
-- values on the left.
SELECT d < 40,   d < 60,   d < 600 FROM t1;
0|0|1

-- No affinity conversions occur. INTEGER values on the left are
-- always less than TEXT values on the right.
SELECT d < '40', d < '60', d < '600' FROM t1;
1|1|1
```


All of the result in the example are the same if the comparisons are commuted - if expressions of the form "a<40" are rewritten as "40>a".

5. Operators

Mathematical operators (+, -, *, /, %, <<, >>, &, and |) interpret both operands as if they were numbers. STRING or BLOB operands automatically convert into REAL or INTEGER values. If the STRING or BLOB looks like a real number (if it has a decimal point or an exponent) or if the value is outside the range that can be represented as a 64-bit signed integer, then it converts to REAL. Otherwise the operand converts to INTEGER. The implied type conversion of mathematical operands is slightly different from [CAST to NUMERIC](#) in that string and BLOB values that look like real numbers but have no fractional part are kept as REAL instead of being converted into INTEGER as they would be for [CAST to NUMERIC](#). The conversion from STRING or BLOB into REAL or INTEGER is performed even if it is lossy and irreversible. Some mathematical operators (% , <<, >>, &, and |) expect INTEGER operands. For those operators, REAL operands are converted into INTEGER in the same way as a [CAST to INTEGER](#). The <<, >>, &, and | operators always return an INTEGER (or NULL) result, but the % operator returns either INTEGER or REAL (or NULL) depending on the type of its operands. A NULL operand on a mathematical operator yields a NULL result. An operand on a mathematical operator that does not look in any way numeric and is not NULL is converted to 0 or 0.0. Division by zero gives a result of NULL.

6. Sorting, Grouping and Compound SELECTs

When query results are sorted by an ORDER BY clause, values with storage class NULL come first, followed by INTEGER and REAL values interspersed in numeric order, followed by TEXT values in collating sequence order, and finally BLOB values in memcmp() order. No storage class conversions occur before the sort.

When grouping values with the GROUP BY clause values with different storage classes are considered distinct, except for INTEGER and REAL values which are considered equal if they are numerically equal. No affinities are applied to any values as the result of a GROUP by clause.

The compound SELECT operators UNION, INTERSECT and EXCEPT perform implicit comparisons between values. No affinity is applied to comparison operands for the implicit comparisons associated with UNION, INTERSECT, or EXCEPT - the values are compared as is.

7. Collating Sequences

When SQLite compares two strings, it uses a collating sequence or collating function (two words for the same thing) to determine which string is greater or if the two strings are equal. SQLite has three built-in collating functions: BINARY, NOCASE, and RTRIM.

- **BINARY** - Compares string data using memcmp(), regardless of text encoding.
- **NOCASE** - The same as binary, except the 26 upper case characters of ASCII are folded to their lower case equivalents before the comparison is performed. Note that only ASCII characters are case folded. SQLite does not attempt to do full UTF case folding due to the size of the tables required.
- **RTRIM** - The same as binary, except that trailing space characters are ignored.

An application can register additional collating functions using the [sqlite3_create_collation\(\)](#) interface.

Collating functions only matter when comparing string values. Numeric values are always compared numerically, and BLOBs are always compared byte-by-byte using memcmp().

7.1. Assigning Collating Sequences from SQL

Every column of every table has an associated collating function. If no collating function is explicitly defined, then the collating function defaults to BINARY. The COLLATE clause of the [column definition](#) is used to define alternative collating functions for a column.

The rules for determining which collating function to use for a binary comparison operator (=, <, >, <=, >=, !=, IS, and IS NOT) are as follows:

1. If either operand has an explicit collating function assignment using the postfix [COLLATE operator](#), then the explicit collating function is used for comparison, with precedence to the collating function of the left operand.
2. If either operand is a column, then the collating function of that column is used with precedence to the left operand. For the purposes of the previous sentence, a column name preceded by one or more unary "+" operators and/or CAST operators is still considered a column name.
3. Otherwise, the BINARY collating function is used for comparison.

An operand of a comparison is considered to have an explicit collating function assignment (rule 1 above) if any subexpression of the operand uses the postfix [COLLATE operator](#). Thus, if a [COLLATE operator](#) is used anywhere in a comparison expression, the collating function defined by that operator is used for string comparison regardless of what table columns might be a part of that expression. If two or more [COLLATE operator](#) subexpressions appear anywhere in a comparison, the left most explicit collating function is used regardless of how deeply the COLLATE operators are nested in the expression and regardless of how the expression is parenthesized.

The expression "x BETWEEN y and z" is logically equivalent to two comparisons "x >= y AND x <= z" and works with respect to collating functions as if it were two separate comparisons. The expression "x IN (SELECT y ...)" is handled in the same way as the expression "x = y" for the purposes of determining the collating sequence. The collating sequence used for expressions of the form "x IN (y, z, ...)" is the collating sequence of x.

Terms of the ORDER BY clause that is part of a [SELECT](#) statement may be assigned a collating sequence using the [COLLATE operator](#), in which case the specified collating function is used for sorting. Otherwise, if the expression sorted by an ORDER BY clause is a column, then the collating sequence of the column is used to determine sort order. If

the expression is not a column and has no COLLATE clause, then the BINARY collating sequence is used.

7.2. Collation Sequence Examples

The examples below identify the collating sequences that would be used to determine the results of text comparisons that may be performed by various SQL statements. Note that a text comparison may not be required, and no collating sequence used, in the case of numeric, blob or NULL values.

```
CREATE TABLE t1(
  x INTEGER PRIMARY KEY,
  a,                /* collating sequence BINARY */
  b COLLATE BINARY, /* collating sequence BINARY */
  c COLLATE RTRIM,  /* collating sequence RTRIM */
  d COLLATE NOCASE  /* collating sequence NOCASE */
);

/* x  a      b      c      d */
INSERT INTO t1 VALUES(1,'abc','abc', 'abc ', 'abc');
INSERT INTO t1 VALUES(2,'abc','abc', 'abc',  'ABC');
INSERT INTO t1 VALUES(3,'abc','abc', 'abc ', 'Abc');
INSERT INTO t1 VALUES(4,'abc','abc ', 'ABC',  'abc');

/* Text comparison a=b is performed using the BINARY collating sequence. */
SELECT x FROM t1 WHERE a = b ORDER BY x;
--result 1 2 3

/* Text comparison a=b is performed using the RTRIM collating sequence. */
SELECT x FROM t1 WHERE a = b COLLATE RTRIM ORDER BY x;
--result 1 2 3 4

/* Text comparison d=a is performed using the NOCASE collating sequence. */
SELECT x FROM t1 WHERE d = a ORDER BY x;
--result 1 2 3 4

/* Text comparison a=d is performed using the BINARY collating sequence. */
SELECT x FROM t1 WHERE a = d ORDER BY x;
--result 1 4

/* Text comparison 'abc'=c is performed using the RTRIM collating sequence. */
SELECT x FROM t1 WHERE 'abc' = c ORDER BY x;
--result 1 2 3

/* Text comparison c='abc' is performed using the RTRIM collating sequence. */
SELECT x FROM t1 WHERE c = 'abc' ORDER BY x;
--result 1 2 3

/* Grouping is performed using the NOCASE collating sequence (Values
** 'abc', 'ABC', and 'Abc' are placed in the same group). */
SELECT count(*) FROM t1 GROUP BY d ORDER BY 1;
--result 4

/* Grouping is performed using the BINARY collating sequence. 'abc' and
** 'ABC' and 'Abc' form different groups */
SELECT count(*) FROM t1 GROUP BY (d || '') ORDER BY 1;
--result 1 1 2

/* Sorting on column c is performed using the RTRIM collating sequence. */
SELECT x FROM t1 ORDER BY c, x;
--result 4 1 2 3

/* Sorting of (c||'') is performed using the BINARY collating sequence. */
```

```
SELECT x FROM t1 ORDER BY (c||''), x;  
--result 4 2 3 1
```

```
/* Sorting of column c is performed using the NOCASE collating sequence. */  
SELECT x FROM t1 ORDER BY c COLLATE NOCASE, x;  
--result 2 4 3 1
```