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The Multihash Data Format  
draft-multiformats-multihash-03

## Abstract

Cryptographic hash functions often have multiple output sizes and encodings. This variability makes it difficult for applications to examine a series of bytes and determine which hash function produced them. Multihash is a universal data format for encoding outputs from hash functions. It is useful to write applications that can simultaneously support different hash function outputs as well as upgrade their use of hashes over time; Multihash is intended to address these needs.

## Feedback

This specification is a joint work product of Protocol Labs (<https://protocol.ai/>), the W3C Digital Verification Community Group (<https://w3c-dvcg.github.io/>), and the W3C Credentials Community Group (<https://w3c-ccg.github.io/>). Feedback related to this specification should be logged in the issue tracker (<https://github.com/w3c-dvcg/multihash/issues>) or be sent to [public-credentials@w3.org](mailto:public-credentials@w3.org) (<mailto:public-credentials@w3.org>). .

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Internet-Draft

The Multihash Data Format

August 2021

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## Table of Contents

<a href="#">1.</a>	Introduction . . . . .	<a href="#">3</a>
<a href="#">2.</a>	The Multihash Fields . . . . .	<a href="#">3</a>
<a href="#">2.1.</a>	Multihash Core Data Types . . . . .	<a href="#">3</a>
<a href="#">2.1.1.</a>	unsigned variable integer . . . . .	<a href="#">4</a>
<a href="#">2.2.</a>	Multihash Fields . . . . .	<a href="#">4</a>
<a href="#">2.2.1.</a>	Hash Function Identifier . . . . .	<a href="#">4</a>
<a href="#">2.2.2.</a>	Digest Length . . . . .	<a href="#">5</a>
<a href="#">2.2.3.</a>	Digest Value . . . . .	<a href="#">5</a>
<a href="#">2.3.</a>	A Multihash Example . . . . .	<a href="#">5</a>
<a href="#">3.</a>	References . . . . .	<a href="#">5</a>
<a href="#">3.1.</a>	Normative References . . . . .	<a href="#">5</a>
<a href="#">3.2.</a>	Informative References . . . . .	<a href="#">5</a>
<a href="#">Appendix A.</a>	Security Considerations . . . . .	<a href="#">6</a>
<a href="#">Appendix B.</a>	Test Values . . . . .	<a href="#">6</a>
<a href="#">B.1.</a>	SHA-1 . . . . .	<a href="#">6</a>
<a href="#">B.2.</a>	SHA-256 . . . . .	<a href="#">6</a>
<a href="#">B.3.</a>	SHA-512/256 . . . . .	<a href="#">6</a>
<a href="#">B.4.</a>	SHA-512 . . . . .	<a href="#">6</a>
<a href="#">B.5.</a>	blake2b512 . . . . .	<a href="#">7</a>
<a href="#">B.6.</a>	blake2b256 . . . . .	<a href="#">7</a>
<a href="#">B.7.</a>	blake2s256 . . . . .	<a href="#">7</a>
<a href="#">B.8.</a>	blake2s128 . . . . .	<a href="#">7</a>
<a href="#">Appendix C.</a>	Acknowledgements . . . . .	<a href="#">7</a>
<a href="#">Appendix D.</a>	IANA Considerations . . . . .	<a href="#">7</a>
<a href="#">D.1.</a>	The Multihash Identifier Registry . . . . .	<a href="#">8</a>
<a href="#">D.2.</a>	The 'mh' Digest Algorithm . . . . .	<a href="#">25</a>
	Authors' Addresses . . . . .	<a href="#">25</a>

## [1.](#) Introduction

Multihash is particularly important in systems which depend on cryptographically secure hash functions. Attacks may break the cryptographic properties of secure hash functions. These cryptographic breaks are particularly painful in large tool ecosystems, where tools may have made assumptions about hash values, such as function and digest size. Upgrading becomes a nightmare, as all tools which make those assumptions would have to be upgraded to use the new hash function and new hash digest length. Tools may face serious interoperability problems or error-prone special casing.

How many programs out there assume a git hash is a SHA-1 hash?

How many scripts assume the hash value digest is exactly 160 bits?

How many tools will break when these values change?

How many programs will fail silently when these values change?

This is precisely why Multihash was created. It was designed for seamlessly upgrading systems that depend on cryptographic hashes.

When using Multihash, a system warns the consumers of its hash values that these may have to be upgraded in case of a break. Even though the system may still only use a single hash function at a time, the use of multihash makes it clear to applications that hash values may use different hash functions or be longer in the future. Tooling, applications, and scripts can avoid making assumptions about the length, and read it from the multihash value instead. This way, the vast majority of tooling - which may not do any checking of hashes - would not have to be upgraded at all. This vastly simplifies the upgrade process, avoiding the waste of hundreds or thousands of software engineering hours, deep frustrations, and high blood pressure.

## 2. The Multihash Fields

A multihash follows the TLV (type-length-value) pattern and consists of several fields composed of a combination of unsigned variable length integers and byte information.

### 2.1. Multihash Core Data Types

The following section details the core data types used by the Multihash data format.

#### 2.1.1. unsigned variable integer

A data type that enables one to express an unsigned integer of variable length.

When encoding an unsigned variable integer, the unsigned integer is serialized seven bits at a time, starting with the least significant bits. The most significant bit in each output byte indicates if there is a continuation byte. It is not possible to express a signed integer with this data type.

Value	Encoding (bits)	hexadecimal notation
1	00000001	0x01
127	01111111	0x7F
128	10000000 00000001	0x8001
255	11111111 00000001	0xFF01
300	10101100 00000010	0xAC02
16384	10000000 10000000 00000001	0x808001

Table 1: Examples of Unsigned Variable Integers

Implementations MUST restrict the size of the varint to a max of nine bytes (63 bits). In order to avoid memory attacks on the encoding, the aforementioned practical maximum length of nine bytes is used. There is no theoretical limit, and future specs can grow this number if it is truly necessary to have code or length values larger than  $2^{31}$ .

## [2.2. Multihash Fields](#)

A multihash follows the TLV (type-length-value) pattern.

### [2.2.1. Hash Function Identifier](#)

The hash function identifier is an unsigned variable integer (#cdt-*uvi*) identifying the hash function. The possible values for this field are provided in The Multihash Identifier Registry (#mh-*registry*).

### [2.2.2. Digest Length](#)

The digest length is an unsigned variable integer (#cdt-*uvi*) counting the length of the digest in bytes.

### [2.2.3. Digest Value](#)

The digest value is the hash function digest with a length of exactly what is specified in the digest length, which is specified in bytes.

## [2.3. A Multihash Example](#)

For example, the following is an expression of a SHA2-256 hash in hexadecimal notation (spaces added for readability purposes):

0x12 20 41dd7b6443542e75701aa98a0c235951a28a0d851b11564d20022ab11d2589a8

The first byte (0x12) specifies the SHA2-256 hash function. The second byte (0x20) specifies the length of the hash, which is 32 bytes. The rest of the data specifies the value of the output of the hash function.

### 3. References

#### 3.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC6234] Eastlake 3rd, D. and T. Hansen, "US Secure Hash Algorithms (SHA and SHA-based HMAC and HKDF)", [RFC 6234](#), DOI 10.17487/RFC6234, May 2011, <<https://www.rfc-editor.org/info/rfc6234>>.
- [RFC7693] Saarinen, M-J., Ed. and J-P. Aumasson, "The BLAKE2 Cryptographic Hash and Message Authentication Code (MAC)", [RFC 7693](#), DOI 10.17487/RFC7693, November 2015, <<https://www.rfc-editor.org/info/rfc7693>>.

#### 3.2. Informative References

- [RFC6150] Turner, S. and L. Chen, "MD4 to Historic Status", [RFC 6150](#), DOI 10.17487/RFC6150, March 2011, <<https://www.rfc-editor.org/info/rfc6150>>.

- [RFC6151] Turner, S. and L. Chen, "Updated Security Considerations for the MD5 Message-Digest and the HMAC-MD5 Algorithms", [RFC 6151](#), DOI 10.17487/RFC6151, March 2011, <<https://www.rfc-editor.org/info/rfc6151>>.

### Appendix A. Security Considerations

There are a number of security considerations to take into account when implementing or utilizing this specification. TBD

### Appendix B. Test Values

The multihash examples are chosen to show different hash functions and different hash digest lengths at play. The input test data for all of the examples in this section is:

## Merkle-Damgård

### [B.1.](#) SHA-1

0x11148a173fd3e32c0fa78b90fe42d305f202244e2739

The fields for this multihash are - hashing function: sha1 (0x11),  
length: 20 (0x14), digest: 0x8a173fd3e32c0fa78b90fe42d305f202244e2739

### [B.2.](#) SHA-256

0x122041dd7b6443542e75701aa98a0c235951a28a0d851b11564d20022ab11d2589a8

The fields for this multihash are - hashing function: sha2-256  
(0x12), length: 32 (0x20), digest:  
0x41dd7b6443542e75701aa98a0c235951a28a0d851b11564d20022ab11d2589a8

### [B.3.](#) SHA-512/256

0x132052eb4dd19f1ec522859e12d89706156570f8fbab1824870bc6f8c7d235eef5f4

The fields for this multihash are - hashing function: sha2-512  
(0x13), length: 32 (0x20), digest:  
0x52eb4dd19f1ec522859e12d89706156570f8fbab1824870bc6f8c7d235eef5f4

### [B.4.](#) SHA-512

0x134052eb4dd19f1ec522859e12d89706156570f8fbab1824870bc6f8c7d235eef5f4c2cbbafd3

The fields for this multihash are - hashing function: sha2-512  
(0x13), length: 64 (0x40), digest: 0x52eb4dd19f1ec522859e12d897061565  
70f8fbab1824870bc6f8c7d235eef5f4c2cbbafd365f96fb12b1d98a0334870c2ce90  
355da25e6a1108a6e17c4aaebb0

### [B.5.](#) blake2b512

0xb24040d91ae0cb0e48022053ab0f8f0dc78d28593d0f1c13ae39c9b169c136a779f21a0496337

The fields for this multihash are - hashing function: blake2b-512 (0xb240), length: 64 (0x40), digest: 0xd91ae0cb0e48022053ab0f8f0dc78d28593d0f1c13ae39c9b169c136a779f21a0496337b6f776a73c1742805c1cc15e792ddb3c92ee1fe300389456ef3dc97e2

#### [B.6.](#) blake2b256

0xb220207d0a1371550f3306532ff44520b649f8be05b72674e46fc24468ff74323ab030

The fields for this multihash are - hashing function: blake2b-256 (0xb220), length: 32 (0x20), digest: 0x7d0a1371550f3306532ff44520b649f8be05b72674e46fc24468ff74323ab030

#### [B.7.](#) blake2s256

0xb26020a96953281f3fd944a3206219fad61a40b992611b7580f1fa091935db3f7ca13d

The fields for this multihash are - hashing function: blake2s-256 (0xb260), length: 32 (0x20), digest: 0xa96953281f3fd944a3206219fad61a40b992611b7580f1fa091935db3f7ca13d

#### [B.8.](#) blake2s128

0xb250100a4ec6f1629e49262d7093e2f82a3278

The fields for this multihash are - hashing function: blake2s-128 (0xb250), length: 16 (0x10), digest: 0x0a4ec6f1629e49262d7093e2f82a3278

### [Appendix C.](#) Acknowledgements

The editors would like to thank the following individuals for feedback on and implementations of the specification (in alphabetical order).

### [Appendix D.](#) IANA Considerations

#### [D.1.](#) The Multihash Identifier Registry



The Multihash Identifier Registry contains hash functions supported by Multihash each with its canonical name, its value in hexadecimal notation, and its status. The following initial entries should be added to the registry to be created and maintained at (the suggested URI) <http://www.iana.org/assignments/multihash-identifiers> (<http://www.iana.org/assignments/multihash-identifiers>):

Name	Identifier	Status	Specification
identity	0x00	active	Unknown
sha1	0x11	active	<a href="#">RFC 6234</a> [ <a href="#">RFC6234</a> ]
sha2-256	0x12	active	<a href="#">RFC 6234</a> [ <a href="#">RFC6234</a> ]
sha2-512	0x13	active	<a href="#">RFC 6234</a> [ <a href="#">RFC6234</a> ]
sha3-512	0x14	active	Unknown
sha3-384	0x15	active	Unknown
sha3-256	0x16	active	Unknown
sha3-224	0x17	active	Unknown
shake-128	0x18	active	Unknown
shake-256	0x19	active	Unknown
keccak-224	0x1a	active	Unknown
keccak-256	0x1b	active	Unknown
keccak-384	0x1c	active	Unknown
keccak-512	0x1d	active	Unknown
blake3	0x1e	active	Unknown
murmur3-128	0x22	active	Unknown
murmur3-32	0x23	active	Unknown

dbl-sha2-256	0x56	active	Unknown
md4	0xd4	deprecated	<a href="#">RFC 6150</a> [RFC6150]
md5	0xd5	deprecated	<a href="#">RFC 6151</a> [RFC6151]
bmt	0xd6	active	Unknown
sha2-256-trunc254-padded	0x1012	active	<a href="#">RFC 6234</a> [RFC6234]
ripemd-128	0x1052	active	Unknown
ripemd-160	0x1053	active	Unknown
ripemd-256	0x1054	active	Unknown
ripemd-320	0x1055	active	Unknown
x11	0x1100	active	Unknown
kangarootwelve	0x1d01	active	Unknown
sm3-256	0x534d	active	Unknown
blake2b-8	0xb201	active	<a href="#">RFC 7693</a> [RFC7693]
blake2b-16	0xb202	active	<a href="#">RFC 7693</a> [RFC7693]
blake2b-24	0xb203	active	<a href="#">RFC 7693</a> [RFC7693]
blake2b-32	0xb204	active	<a href="#">RFC 7693</a> [RFC7693]
blake2b-40	0xb205	active	<a href="#">RFC 7693</a> [RFC7693]
blake2b-48	0xb206	active	<a href="#">RFC 7693</a> [RFC7693]

	blake2b-56		0xb207		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	

+-----+-----+-----+-----+								
	blake2b-64		0xb208		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-72		0xb209		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-80		0xb20a		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-88		0xb20b		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-96		0xb20c		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-104		0xb20d		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-112		0xb20e		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-120		0xb20f		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-128		0xb210		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-136		0xb211		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-144		0xb212		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-152		0xb213		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	
+-----+-----+-----+-----+								
	blake2b-160		0xb214		active		<a href="#">RFC 7693</a>	
							<a href="#">[RFC7693]</a>	

blake2b-168	0xb215	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-176	0xb216	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-184	0xb217	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>

blake2b-192	0xb218	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-200	0xb219	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-208	0xb21a	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-216	0xb21b	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-224	0xb21c	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-232	0xb21d	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-240	0xb21e	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-248	0xb21f	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-256	0xb220	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-264	0xb221	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
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			<a href="#">[RFC7693]</a>
blake2b-280	0xb223	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
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blake2b-344	0xb22b	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-352	0xb22c	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2b-360	0xb22d	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
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blake2b-376	0xb22f	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>

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blake2b-504	0xb23f	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
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blake2s-112	0xb24e	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-120	0xb24f	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-128	0xb250	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-136	0xb251	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-144	0xb252	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-152	0xb253	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-160	0xb254	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-168	0xb255	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-176	0xb256	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-184	0xb257	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>

blake2s-192	0xb258	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
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blake2s-200	0xb259	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-208	0xb25a	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-216	0xb25b	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-224	0xb25c	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-232	0xb25d	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-240	0xb25e	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-248	0xb25f	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
blake2s-256	0xb260	active	<a href="#">RFC 7693</a> <a href="#">[RFC7693]</a>
skein256-8	0xb301	active	Unknown
skein256-16	0xb302	active	Unknown
skein256-24	0xb303	active	Unknown
skein256-32	0xb304	active	Unknown
skein256-40	0xb305	active	Unknown
skein256-48	0xb306	active	Unknown
skein256-56	0xb307	active	Unknown
skein256-64	0xb308	active	Unknown
skein256-72	0xb309	active	Unknown
skein256-80	0xb30a	active	Unknown

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	skein256-240		0xb31e		active		Unknown	
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	skein512-16		0xb322		active		Unknown	

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	skein512-208		0xb33a		active		Unknown	
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	skein512-224		0xb33c		active		Unknown	
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	skein512-232		0xb33d		active		Unknown	
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skein512-352	0xb34c	active	Unknown
skein512-360	0xb34d	active	Unknown
skein512-368	0xb34e	active	Unknown
skein512-376	0xb34f	active	Unknown
skein512-384	0xb350	active	Unknown
skein512-392	0xb351	active	Unknown
skein512-400	0xb352	active	Unknown

skein512-408	0xb353	active	Unknown
skein512-416	0xb354	active	Unknown
skein512-424	0xb355	active	Unknown
skein512-432	0xb356	active	Unknown
skein512-440	0xb357	active	Unknown
skein512-448	0xb358	active	Unknown
skein512-456	0xb359	active	Unknown
skein512-464	0xb35a	active	Unknown
skein512-472	0xb35b	active	Unknown
skein512-480	0xb35c	active	Unknown
skein512-488	0xb35d	active	Unknown
skein512-496	0xb35e	active	Unknown
skein512-504	0xb35f	active	Unknown

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skein1024-176	0xb376	active	Unknown
skein1024-184	0xb377	active	Unknown
skein1024-192	0xb378	active	Unknown
skein1024-200	0xb379	active	Unknown
skein1024-208	0xb37a	active	Unknown
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skein1024-232	0xb37d	active	Unknown
skein1024-240	0xb37e	active	Unknown
skein1024-248	0xb37f	active	Unknown
skein1024-256	0xb380	active	Unknown
skein1024-264	0xb381	active	Unknown
skein1024-272	0xb382	active	Unknown

skein1024-280	0xb383	active	Unknown
skein1024-288	0xb384	active	Unknown
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skein1024-312	0xb387	active	Unknown
skein1024-320	0xb388	active	Unknown

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	skein1024-488		0xb39d		active		Unknown	



skein1024-496	0xb39e	active	Unknown
skein1024-504	0xb39f	active	Unknown
skein1024-512	0xb3a0	active	Unknown
skein1024-520	0xb3a1	active	Unknown
skein1024-528	0xb3a2	active	Unknown
skein1024-536	0xb3a3	active	Unknown
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skein1024-560	0xb3a6	active	Unknown
skein1024-568	0xb3a7	active	Unknown
skein1024-576	0xb3a8	active	Unknown
skein1024-584	0xb3a9	active	Unknown
skein1024-592	0xb3aa	active	Unknown
skein1024-600	0xb3ab	active	Unknown
skein1024-608	0xb3ac	active	Unknown
skein1024-616	0xb3ad	active	Unknown
skein1024-624	0xb3ae	active	Unknown
skein1024-632	0xb3af	active	Unknown
skein1024-640	0xb3b0	active	Unknown
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	skein1024-680		0xb3b5		active		Unknown	
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	skein1024-688		0xb3b6		active		Unknown	
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	skein1024-696		0xb3b7		active		Unknown	
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	skein1024-712		0xb3b9		active		Unknown	
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	skein1024-728		0xb3bb		active		Unknown	
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	skein1024-816		0xb3c6		active		Unknown	
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	skein1024-824		0xb3c7		active		Unknown	
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	skein1024-832		0xb3c8		active		Unknown	
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	skein1024-840		0xb3c9		active		Unknown	
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	skein1024-848		0xb3ca		active		Unknown	
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Internet-Draft

The Multihash Data Format

August 2021

	skein1024-856		0xb3cb		active		Unknown	
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	skein1024-864		0xb3cc		active		Unknown	
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	skein1024-872		0xb3cd		active		Unknown	
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	skein1024-880		0xb3ce		active		Unknown	
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	skein1024-888		0xb3cf		active		Unknown	
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	skein1024-920		0xb3d3		active		Unknown	
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	skein1024-952		0xb3d7		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-960		0xb3d8		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-968		0xb3d9		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-976		0xb3da		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-984		0xb3db		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-992		0xb3dc		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-1000		0xb3dd		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-1008		0xb3de		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+
	skein1024-1016		0xb3df		active		Unknown	
+-----+		+-----+		+-----+		+-----+		+-----+

skein1024-1024	0xb3e0	active	Unknown	
+-----+	+-----+	+-----+	+-----+	+-----+
poseidon-bls12_381-a2-fc1	0xb401	active	Unknown	
+-----+	+-----+	+-----+	+-----+	+-----+
poseidon-bls12_381-a2-fc1-sc	0xb402	active	Unknown	
+-----+	+-----+	+-----+	+-----+	+-----+

Table 2: Multihash Identifier Registry

NOTE: The most up to date place for developers to find the table above is <https://github.com/multiformats/multicodec/blob/master/table.csv> (<https://github.com/multiformats/multicodec/blob/master/table.csv>).

## D.2. The 'mh' Digest Algorithm

This memo registers the "mh" digest-algorithm in the HTTP Digest Algorithm Values (<https://www.iana.org/assignments/http-dig-alg/http-dig-alg.xhtml>) registry with the following values:

Digest Algorithm: mh

Description: The multibase-serialized value of a multihash-supported algorithm.

References: this document

Status: standard

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