

RESTFUL SERVICES

CSE416, Section 1

Will be tested in the client/server
review (10/9 and 10/15)

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Lecture Objectives

- Understand the fundamental concepts of Web services
- Understand the components of a RESTful interface
- Understand concepts of HTTP
- Become familiar with Jakarta REST (formerly JAX-RS) annotations
- Be able to build a simple Web service
- Understand how to pass parameters and return values with Web services

“Java” to “Jakarta” name change
due to licensing issues with Oracle

Parts of Spring are very
similar to Jakarta REST

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Reading & References

- Reading
 - Tutorials
 - <https://jakarta.ee/learn/docs/jakartaee-tutorial/current/index.html>
(Page 63 - 123)

Currently being updated, so JAX-RS documentation might be helpful

Session material follows Jakarta EE 10 Tutorial text (formerly Java EE Tutorial)

Jakarta REST was formerly documented as JAX-RS in Chapters 27 and 29 of the Java EE Tutorial at docs.oracle.com/javaee/7/tutorial/webservices-intro.htm#GIJTI

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Client/Server Strategies

- Generation of HTML/CSS
 - Server responds with a dynamically generated page that includes HTML, CSS, and data (inserted in the page)
 - Data insertion usually performed by a server-side scripting engine
- Web services
 - Server responds with data (no HTML and CSS)
 - Data structured based on some coordination between client and server (e.g., JSON, XML, text)

Most/all GUI components in your CSE416 project should be implemented with web services

HTTP and the Servlet API are the standards used to implement many client/server frameworks

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Servlets

No need to use servlets directly, but you should understand how they function

- Conforms to the Java Servlet API
- Normally used to implement Jakarta REST and other client/server frameworks
- A servlet:
 - Is a Java class that can be loaded dynamically to expand the capability of the Web server
 - Runs inside the Java Virtual Machine on the server (safe and portable)
 - Can access all Java APIs supported in the server
 - Does not have a main method
 - Is managed by the web container

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Servlet API

Acts as the controller in an MVC design

- Part of Jakarta EE
- Low level approach to implement server handling of HTTP requests
- Servlet method signature contains a
 - request object that contains parameters, http headers, etc.
 - response object that contains typically empty objects to be populated and returned by the server
- URL requests are mapped to the servlet through annotation or an xml document
- Typically, one servlet per type of request => complicated control logic

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Client – Servlet Model with Servlet API

- Requires multiple servlets to handle requests
- Requires logic in servlet to route each request to a service method
- Mapping of the URL to a servlet is handled with web.xml or Java Annotation in servlet class

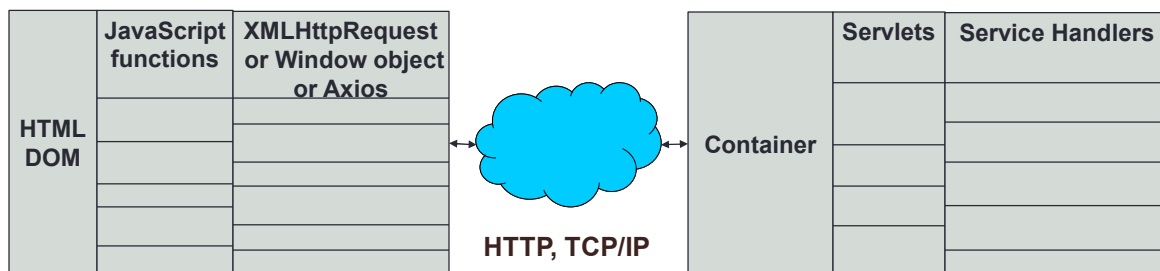
```
<form method="get" action=
"http://localhost:8080/CSE416/helloyou.html">
```

Servlet identified by the “helloyou.html” URL string usually acts as a controller, and routes to a service handler

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Servlet API Client/Server Interaction

Basic client/server interaction



Parts of the client/server interaction are abstracted by tools/libraries

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RESTful Web Services

- Representational State Transfer
- Architectural style for distributed systems
- Architecturally consistent with HTTP
- Provides a standard means of interoperating between software applications running on a variety of platforms and frameworks
- Use existing W3C and IETF standards (HTTP, XML, URI, MIME)

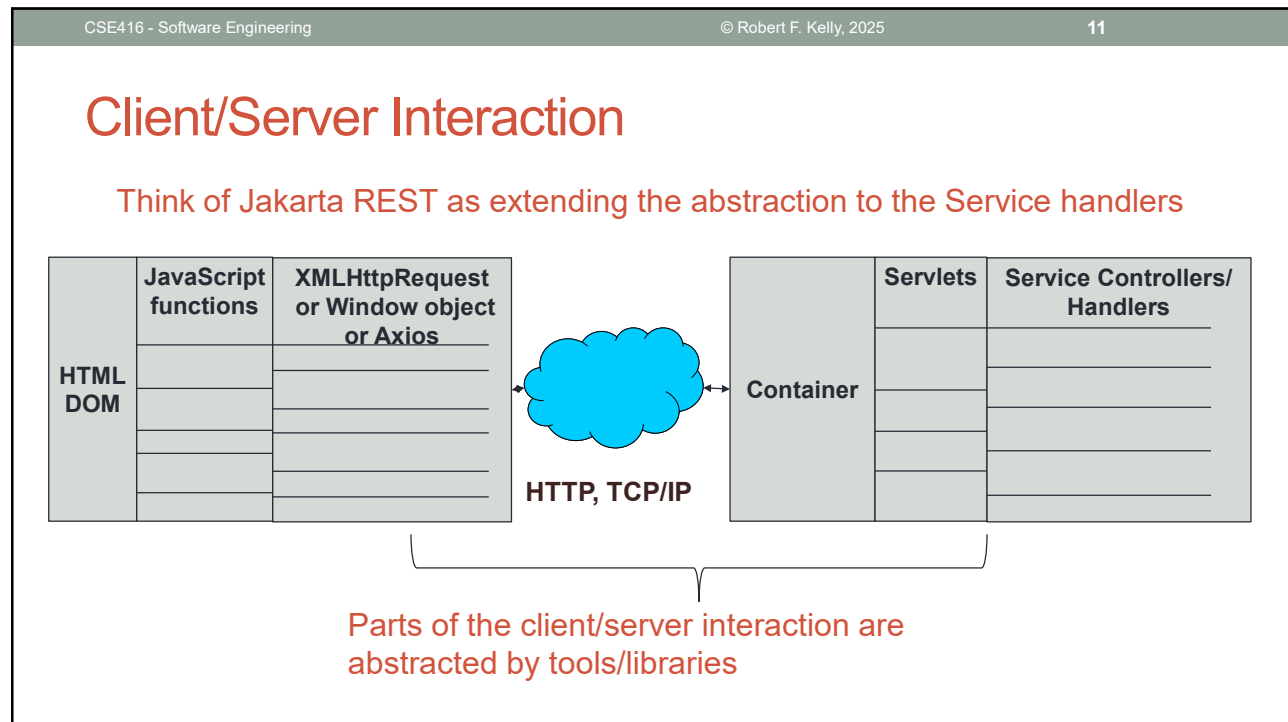
A service is a software component provided through a network-accessible endpoint

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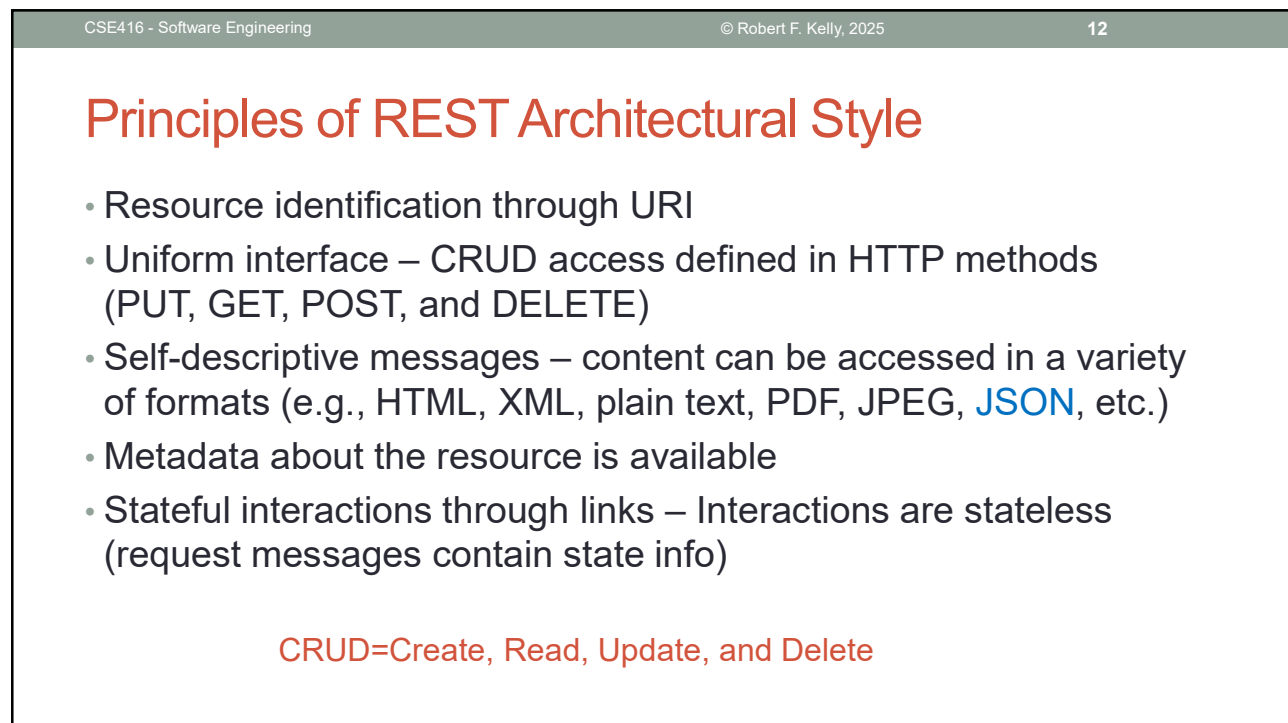
Jakarta REST (formerly JAX-RS)

- Java API for RESTful Web Services
- A standard – not a product
- Reference implementations
 - Jersey, RESTeasy, et al, along with some application servers
 - No requirement to implement on top of servlets, but many implementations do

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Implications of REST Style

- Interactions are predominantly computer-computer, not human-computer
- Resource based URI
- Typically published as an API (but probably not in your project), so design and URI naming important
- Expanded and more precise use of HTTP methods
- Expanded use of HTTP status codes
- Content negotiation between client and server

URI requests are usually
nouns, not verbs

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HTTP

- HyperText Transfer Protocol defines communications between a browser and a server
- Defined in specs (HTTP 1.0, HTTP 1.1, HTTP/2, HTTP/3)
- Defines:
 - Types of messages exchanged (request and response)
 - Syntax of the messages
 - Semantics of the message content
 - Rules for determining how and when a process sends and responds to a message

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HTTP Protocol

- HTTP is a request/response (stateless) protocol
 - A client sends a request to the server in the form of a request method, URI, and protocol version, followed by a MIME-like message containing request modifiers, client information, and possible body content
 - The server responds with a status line, including the message's protocol version and a success (or error) code, followed by a MIME-like message containing server information, entity meta-information, and possible entity-body content.

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Request Message Format

- The http request is specified by the request line, a variable number of header fields, and the entity body

method	sp	URL	sp	Version	cr	If	← request line
header field name	sp	value	cr	If	← header lines		
header field name	sp	value	cr	If			
header field name	sp	value	cr	If			
cr	If						← Entity body

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HTTP Methods

- OPTIONS – request for information concerning communications options (e.g., support of http 1.1)
- GET – retrieve information
- HEAD – identical to GET, except the server does not return a message body
- POST – modify a server resource
- PUT – store the enclosed entity
- DELETE – request that the resource be deleted
- TRACE – response contains the entire message request in the response body
- CONNECT – used in SSL tunneling

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HTTP Request/Response

HTTP-TRACKER Chrome Plugin

Request Details	Response Details																																																																										
<table><thead><tr><th colspan="2">Headers</th></tr></thead><tbody><tr><td>documentLifecycle</td><td>active</td></tr><tr><td>frameType</td><td>outermost_frame</td></tr><tr><td>method</td><td>GET</td></tr><tr><td>url</td><td>https://www3.cs.stonybrook.edu/~cse416/Section01/</td></tr><tr><td>Accept</td><td>text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.9</td></tr><tr><td>Accept-Encoding</td><td>gzip, deflate, br</td></tr><tr><td>Accept-Language</td><td>en-US,en;q=0.9</td></tr><tr><td>sec-ch-ua</td><td>"Google Chrome";v="105", "Not)A;Brand";v="8", "Chromium";v="105"</td></tr><tr><td>sec-ch-ua-mobile</td><td>?0</td></tr><tr><td>sec-ch-ua-platform</td><td>"Windows"</td></tr><tr><td>Sec-Fetch-Dest</td><td>document</td></tr><tr><td>Sec-Fetch-Mode</td><td>navigate</td></tr><tr><td>Sec-Fetch-Site</td><td>none</td></tr><tr><td>Sec-Fetch-User</td><td>?1</td></tr><tr><td>Upgrade-Insecure-Requests</td><td>1</td></tr><tr><td>User-Agent</td><td>Mozilla/5.0 (Windows NT 10.0; Win64; x64</td></tr></tbody></table>	Headers		documentLifecycle	active	frameType	outermost_frame	method	GET	url	https://www3.cs.stonybrook.edu/~cse416/Section01/	Accept	text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.9	Accept-Encoding	gzip, deflate, br	Accept-Language	en-US,en;q=0.9	sec-ch-ua	"Google Chrome";v="105", "Not)A;Brand";v="8", "Chromium";v="105"	sec-ch-ua-mobile	?0	sec-ch-ua-platform	"Windows"	Sec-Fetch-Dest	document	Sec-Fetch-Mode	navigate	Sec-Fetch-Site	none	Sec-Fetch-User	?1	Upgrade-Insecure-Requests	1	User-Agent	Mozilla/5.0 (Windows NT 10.0; Win64; x64	<table><thead><tr><th colspan="2">Headers</th></tr></thead><tbody><tr><td>documentLifecycle</td><td>active</td></tr><tr><td>frameType</td><td>outermost_frame</td></tr><tr><td>fromCache</td><td>false</td></tr><tr><td>ip</td><td>130.245.27.3</td></tr><tr><td>method</td><td>GET</td></tr><tr><td>statusCode</td><td>200</td></tr><tr><td>statusLine</td><td>HTTP/1.1 200 OK</td></tr><tr><td>url</td><td>https://www3.cs.stonybrook.edu/~cse416/Section01/</td></tr><tr><td>Accept-Ranges</td><td>bytes</td></tr><tr><td>Connection</td><td>Keep-Alive</td></tr><tr><td>Content-Encoding</td><td>gzip</td></tr><tr><td>Content-Length</td><td>7608</td></tr><tr><td>Content-Type</td><td>text/html</td></tr><tr><td>Date</td><td>Tue, 13 Sep 2022 17:56:28 GMT</td></tr><tr><td>ETag</td><td>"5923-5e830a268ed4f-gzip"</td></tr><tr><td>Keep-Alive</td><td>timeout=5, max=100</td></tr><tr><td>Last-Modified</td><td>Thu, 08 Sep 2022 20:54:24 GMT</td></tr><tr><td>Server</td><td>Apache/2.4.18 (Ubuntu)</td></tr><tr><td>Vary</td><td>Accept-Encoding</td></tr></tbody></table>	Headers		documentLifecycle	active	frameType	outermost_frame	fromCache	false	ip	130.245.27.3	method	GET	statusCode	200	statusLine	HTTP/1.1 200 OK	url	https://www3.cs.stonybrook.edu/~cse416/Section01/	Accept-Ranges	bytes	Connection	Keep-Alive	Content-Encoding	gzip	Content-Length	7608	Content-Type	text/html	Date	Tue, 13 Sep 2022 17:56:28 GMT	ETag	"5923-5e830a268ed4f-gzip"	Keep-Alive	timeout=5, max=100	Last-Modified	Thu, 08 Sep 2022 20:54:24 GMT	Server	Apache/2.4.18 (Ubuntu)	Vary	Accept-Encoding
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HTTP Request Headers

- Accept
- Accept-charset
- Accept-encoding
- Accept-language
- Authorization
- Cache-control
- Connection
- Content-length
- Content-type
- Cookie
- Expect
- From
- Host
- If-match
- If-modified-since
- If-none-match
- If-range
- If-unmodified-since
- Pragma
- Proxy-authorization
- Range
- Referer
- Upgrade
- User-agent
- Via

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HTTP Response Message

- HTTP response messages consist of:
 - Status line (protocol version, status code, status message)
 - Header lines (date, server, last-modified, content-length, content-type)
 - Entity body

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HTTP Status Codes

- Examples:
 - 200 – OK
 - 100 – Continue
 - 404 – Not found

There are other codes in http that might allow you to distinguish categories of errors

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HTTP Response Headers

• Accept-Ranges	• Date
• Age	• Etag
• Allow	• Expires
• Cache-Control	• Last-Modified
• Connection	• Location
• Content-Encoding	• Refresh
• Content-Language	• Server
• Content-Length	• Set-Cookie
• Content-MD5	• Via
• Content-Type	• Warning

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Example

- We start by building a very simple RESTful Web service
- Later we will extend this by
 - Passing parameters to the server
 - Negotiating content
 - Returning content

For all the examples, think of accessing the resources from your html/JavaScript running in your browser

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Creating a RESTful Root Resource Class

- Root resource classes are POJOs (plain old Java objects)
- Annotated with `@Path` or a request method designator (`@GET`, `@PUT`, `@POST`, or `@DELETE`)

Jakarta REST uses Java Annotations

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Jakarta REST Annotation Summary ...

Annotation	Description
@PATH	Relative URI indicating where the class will be hosted. Can also embed variables (e.g., /helloworld/{username})
@GET	Corresponds to the HTTP GET method. A Java method annotated with @GET will handle GET requests
@POST	Corresponds to the HTTP POST method
@PUT	Corresponds to HTTP PUT method. Intended for resource updates
@DELETE	Corresponds to HTTP DELETE method

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... Jakarta TEST Annotation Summary

Annotation	Description
@HEAD	Corresponds to HTTP Method.
@PathParam	Parameter extracted from the request URI. Parameter names correspond to the URI path template variable names specified in the @PATH annotation
@QueryParam	Extracted from the query string
@Consumes	Specifies the MIME type sent by client
@Produces	Specifies the MIME type produced (e.g., "text/plain")
@ApplicationPath	Defines the URL mapping. Base URI for all resource URIs specified by @Path

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IDE Support

- Your IDE will likely feature support for a RESTful service
 - Java Web project
 - Reference implementation of Jakarta REST (e.g., Glassfish)
 - Correct application directory
 - Some starter code

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HelloWorld.java

```
@Path("helloworld")
public class HelloWorld {
    @Context
    private UriInfo context;

    public HelloWorld() {
    }

    @GET
    @Produces(MediaType.TEXT_HTML)
    public String getHtml() {
        return "<html><body><h1>Hello, World!!</h1></body></html>";
    }

    @PUT
    @Consumes(MediaType.TEXT_HTML)
    public void putHtml(String content) {
    }
}
```

This http GET request will return html

Identifies the MIME type of the response

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MediaType Class

- An abstraction for Jakarta REST media types
- Contains String constants
- Examples
 - TEXT_HTML – “text/html”
 - TEXT_PLAIN – “text/plain”
 - APPLICATION_JSON – “application/json”

Best to use the MediaType constant strings to avoid typing errors

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Passing Parameters to a RESTful Service

- Without using the servlet parameters (request and response) directly, we need a different way to pass parameters from the client to the server
 1. Use the **url query string** (form data set)
 - Parameters are mapped to arguments in the method signature
 2. Use the URL
 - URI components become an argument to the method responding to the request

`http://example.com/users/Kelly`

← Acts as a parameter

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Extracting Query Parameters – URL Query String

- Your web service can extract parameters in form dataset

```

@Path("/smooth")
@GET
public Response smooth(
    @DefaultValue("2") @QueryParam("step") int step,
    @DefaultValue("true") @QueryParam("min-m") boolean hasMin,
    @DefaultValue("true") @QueryParam("max-m") boolean hasMax,
    @DefaultValue("true") @QueryParam("last-m") boolean hasLast,
    @DefaultValue("blue") @QueryParam("min-color") ColorParam minColor,
    @DefaultValue("green") @QueryParam("max-color") ColorParam maxColor,
    @DefaultValue("red") @QueryParam("last-color") ColorParam lastColor
) { ... }
```

The form dataset is contained in the URL for a GET

Instantiated with the user-defined class constructor

Notice that parameters are parsed into Java types

Missing parameters assume default value

A 400 error code is returned if parameter cannot be parsed

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Extracting Form Parameters from POST Request

- Recall that form parameters in a POST request are not contained in the URL (they are in the HTTP body)

```

@POST
@Consumes("application/x-www-form-urlencoded")
public void post(@FormParam("name") String name) {
    // Store the message
}
```

Other annotation exists to extract a Map of name-value pairs

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Data Exchange

- We define the data exchanged by using annotation for Produces and Consumes
- Content format is negotiated by the client and server based on the annotation and the ability of each to handle various formats

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@Consumes

- @jakarta.ws.rs.Consumes
- Defines the MIME type the server methods can accept
- Defined at either the class level or the method level
- Selected values
 - application/json
 - application/octet-stream
 - text/html
 - text/plain
 - multipart/form-data
 - application/x-www-form-urlencoded

Example

```
@Consumes ({MediaType.TEXT_PLAIN,  
            MediaType.TEXT_HTML})
```

Typical browser encoding of
the form data set

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@Produces

- Defines the MIME type that a REST resource class method can return to the client
- Defined at either the class level (defaults for all methods) or method level
- Selected values
 - application/json
 - application/octet-stream
 - text/html
 - text/plain

Example

```
@Produces ({"image/jpeg", "image/png"})
```

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Path Templates

- A path can be defined with a path template – placeholder for a value to be defined by the user

Example: <http://example.com/users/Kelly>

- Parameter is obtained in the following example

```
@Path("/users/{username}")
public class UserResource {
    @GET
    @Produces("text/html")
    public String getUser(@PathParam("username") String
        userName) {
        ...
    }
}
```

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Web Resources Style

- The PathParameter annotation provides a different style in requesting Web resources
- Example
`localhost:8080/CSE336-Services/library/librarycards/124`
- Made to appear as a data retrieval where the path (e.g., librarycards) appears as a plural data resource, and the path parameter (e.g., 124) appears as if it were an index in the repository for the data resource

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@Produces Annotation

- The above example returned HTML that displays as

```
@GET
@Produces(MediaType.TEXT_HTML)
public String getCard(@PathParam("cnum") int cardNumber) {
    String s1 = "<html><body><h1>";
    String s2 = "</h1></body></html>";
    String message = "";
    if (cardNumber==123){
        message="{num:123, nickname:'Alonzo' type:'Adult'}";
        return s1+message+s2; }
    else {return s1 + "Would you like to apply for a library card?" +
s2; } }
```

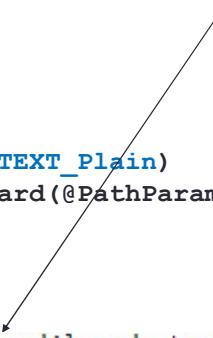
`{num:123, nickname:'Alonzo' type:'Adult'}`

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@Produces Example

- If we change the @Produces annotation, the response is not evaluated as HTML, and only appears as plain text

```
@GET
@Produces(MediaType.TEXT_PLAIN)
public String getCard(@PathParam("cnum") int cardNumber)
{
    <h1><body><h1>{num:123, nickname:'Alonzo', type:'Adult'}</h1></body></html>
```



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@Produces Example

- If we again change the @Produces annotation, when called with localhost:8080/CSE416-Services/library/librarycards/125 it returns the JSON string

```
@GET
@Produces(MediaType.APPLICATION_JSON)
public String getCard(@PathParam("cnum") int cardNumber) {
    String message="{num:125, nickname:'Alonzo' type:'Adult'}";
    if (cardNumber==125){
        return message;
    }
}
```

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Have You Achieved the Lecture Objectives?

- Understand the fundamental concepts of Web services
- Understand the components of a RESTful interface
- Understand concepts of HTTP
- Become familiar with JAX-RS annotations
- Be able to build a simple Web service
- Understand how to pass parameters and return values with Web services