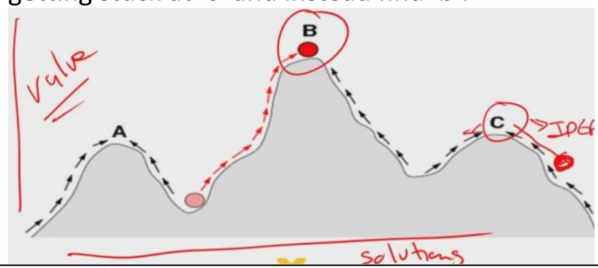
Session 9: Diversity and Innovation

9.1 – Problem Solving and Innovation

Problem Solving:
- Diversity and Recombination (Remixing of Ideas)
- Problem: you take an action, a, and there is a 'payoff' function, F, that gives the value to you of that action, F(a).
  1) writing faster code, 2) more efficient health care policy.
- Want to know where innovation comes from.

Landscape Metaphor: Want to see how people come up with these ideas also how to avoid getting stuck at 'c' and instead find 'b'.



Perspectives: How you represent a problem (in your head or on paper or in code or . . .
1. Encode the problem
2. Create value-solutions landscape

Heuristics: How you move on the landscape.
1. Hill climbing is one heuristics.
2. Random search is another. (A* search is another).

Individuals and Teams:
- Teams have different perspectives and different heuristics, and all that diversity makes them better than individuals on average.

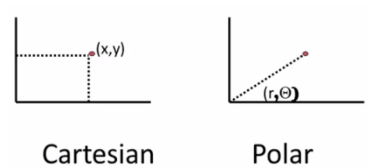
Recombination:
- **Big Idea:** Solutions from one problem and a solution from another problem are combined to make a better solution.
- Recombining solutions from a number of sub-problems yields better solutions.

Summary: Recall how growth is dependent upon sustained innovation. Diversity leads to innovations and recombination of innovations leads to even more innovation. Will start with perspectives, then discuss heuristics, and how teams leverage their diverse perspectives in heuristics.

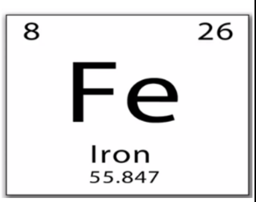
9.2 – Perspectives and Innovation

Perspective:
- A representation of the set of all possible solutions.
- Landscape the possible solutions with their values.

Example of a Perspective:
Plotting Points
$(x,y) \sim (r,\theta)$
Use (x,y) for straight lines,
Use (r,θ) for curve



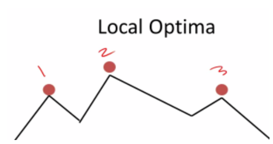
New Perspectives – Old Problems:
Mendelev – Table of elements structure by atomic weight, gaps found.

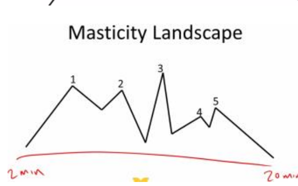


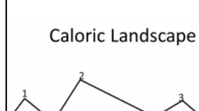
- Iron: 1869
- Scandium: 1879
- Galium: 1875
- Germanium: 1886

Perspective Examples: Hiring a new employee
- Value Competence: GPA
- Value Work Ethic: Thickness application
- Value Creativity: Colorful and interesting

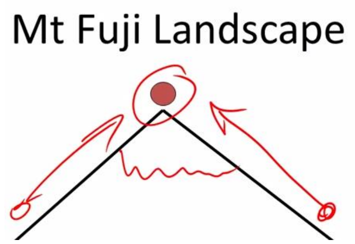
Many **different ways** to organize perspectives. Context suggests which is most useful.
- **Better perspectives** have ***fewer local optima***.
- Calories vs. Masticity (chew time) for candy bars



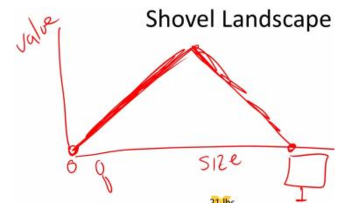




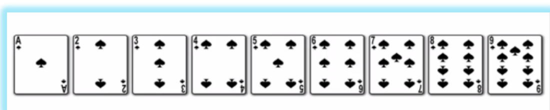
Mt Fuji Landscape:



Shovel Landscape - Frederick Taylor, Scientific Management. Example of single peak, maximum shovel size for coal shoveling



Sum to Fifteen: Herb Simon
Cards numbered 1-9 face up on table. Players alternate selecting cards. Win if you hold exactly three cards that sum to 15.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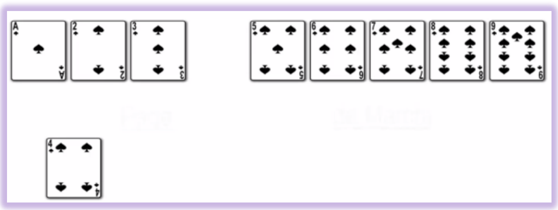
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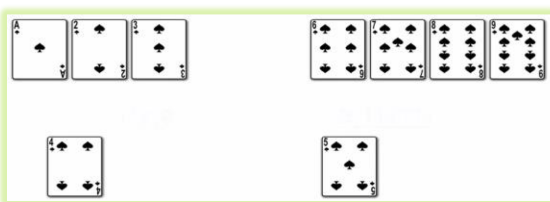
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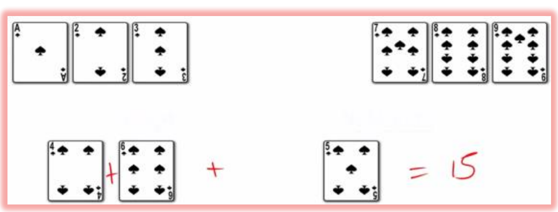

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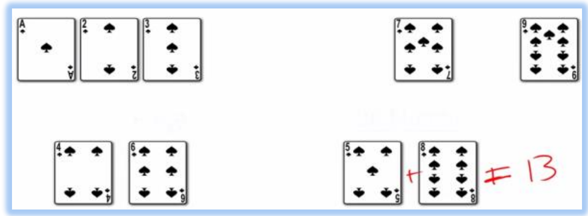
Sum to Fifteen (cont.):



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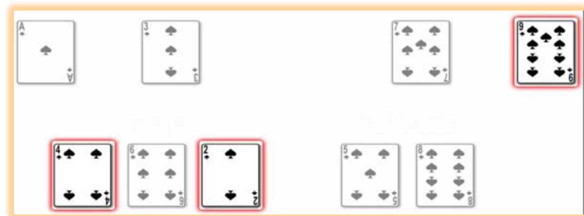
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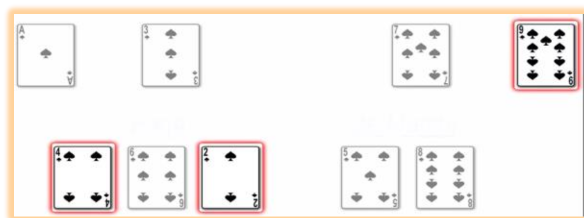
or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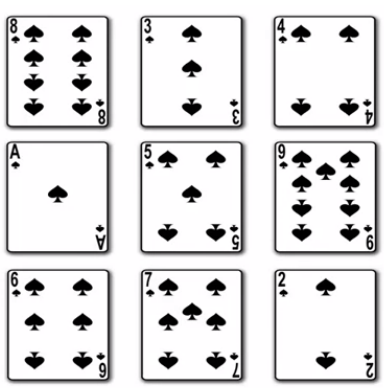
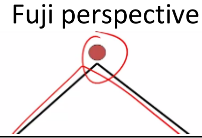
Sum to Fifteen (cont.): Magic Square

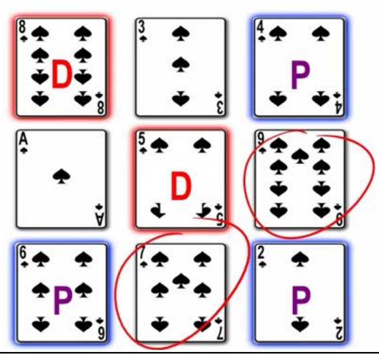
Each Row Sum = Each Column Sum = Each Diagonal Sum = 15



Sum to Fifteen (Play it Again with Magic Square):
More sophisticated tic-tack-toe like game.

- Follow card play as in previous linear perspective.
- Note: now Mt Fuji perspective





Savant Existence Theorem: For any problem there exists a perspective that creates a Mt Fuji landscape (in fact many do). Order solutions in pyramid shape, but you have to know the best to do this?

Bad Perspectives: With N alternatives there are N! (10*9*8 . . .) ways to create one dimensional landscapes. Most will be bad and have many local minimums. And random ordering of solutions is going to create many local minimums.

Overview: Many perspectives. Most are bad with many local maximums and minimums. Insights can identify a perspective that is good with only a single local=global maximum.

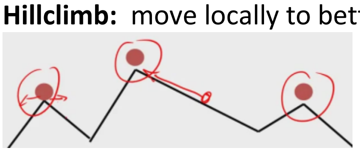
Quiz: Which of the following is a possible perspective for all of the buildings in New York City? (a) Height in feet (b) Decade of construction (c) Number of windows (d) All of the above
Ans: (d) All of the above
Explanation: *All of the options represent a way to organize the problem. In other words, height, age, and number of windows are all perspectives for buildings in New York City. We can then apply heuristics - which we'll talk about in the next section - to investigate what specific height, age, and number of windows is best for whatever our purpose is.*

Summary: ***First step*** is to encode a problem into a presentation, preferably one that yields a Mt. Fuji perspective of the possible solutions. Next use ***Heuristic*** to search the landscape.

9.3 – Heuristics

Heuristic: A tool or a way to search for a solution.

- **Hillclimb:** move locally to better solutions



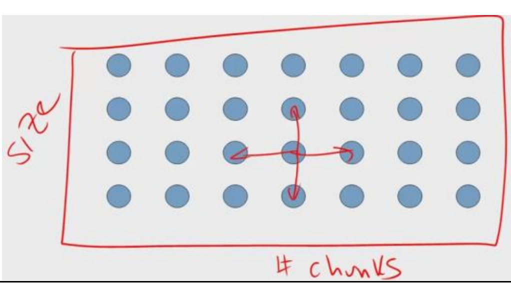
- **Do the Opposite**: take existing or traditional solution and consider doing the opposite. (Priceline, Hotwire)
- **Big Rocks First**!: (Steve Covey) Metaphor big and little rocks in a bucket. Filling with big rocks (most important tasks / goals) first is more efficient.

No Free Lunch: Wolpert & McCready

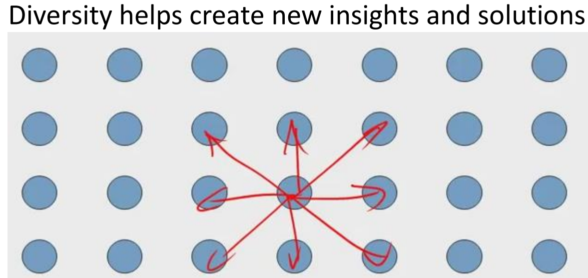
- All algorithms that search the same number of points with the goal of locating the maximum value of a function defined on a finite set perform exactly the same when averaged over all possible functions.
- That is – Context determines most efficient algorithm. Unless you know something about the problem being solved, no algorithm or heuristic performs better than any other. Covey understands his context and hence the most efficient heuristic.
- Some problems are little rocks first.

Quiz: Which of the following is true about the No Free Lunch Theorem? (a) We should beware of savants telling us fail safe rules. (b) Some heuristics are always more effective than others, regardless of the type of problem. (c) The No Free Lunch theorem does not apply when one is looking at a specific type of problem. (d) For any algorithm, any positive performance in one class of problems is paid for by lesser performance in another class.
Ans: (a), (c), (d)
Explanation: *All of these are true except for B, which is untrue because the No Free Lunch Theorem tells us that no single heuristic is always effective. A heuristic that works great for one problem class may be ineffective for another problem type.*

Diverse Heuristics: Search N-S & E-W

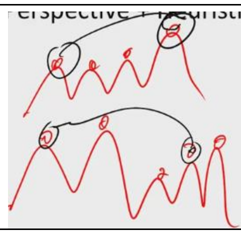


Combine NW-SE & SW-NE with N-S & E-W:
Diversity helps create new insights and solutions



Perspective + Heuristics:

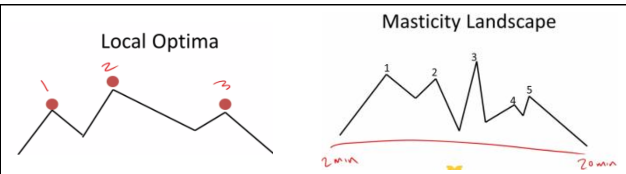
Local hill climbing perspective combined with a random search perspective



Summary: No Free Lunch Theorem suggests that our heuristics are best selected when we firstunderstand something about the problem. An improved perspective can invoke more efficient heuristics. Diversity of perspectives can lead to better problem solutions.

9.4 – Teams and Problem Solving

Collections of People Improve Ideas:
Example: Candy Bar
Caloric and masticity metrics.
Caloric Peaks: 1, 2, 3 ~ (A, B, C)
Masticity peaks: 1, 2, 3, 4, 5 ~ (A, B, C, D, E)
Recall the best possible point has to be a peak in every landscape (perspective). Also better perspectives have fewer local optimum. How good you are can be measured by the number of local maximums and your search heuristic.



Using Values for Peaks – Candy Bar Example:

Peak	A	B	D	E	F
Value	10	8	6	2	4

Ability:

Average Value of Peaks: Caloric

Peak	A	B	C
Value	10	8	6

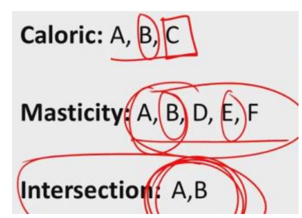
Ability: $average\ value = 8$

Average Value of Peaks: Caloric

Peak	A	B	D	E	F
Value	10	8	6	2	4

Ability: $average\ value = 6$

Team Solution: ***Intersection Property***
Reduces local minima where they can get stuck when they share their 'peaks'.
Only place the 'team' can get stuck is where everyone gets stuck (A,B)



Average Value of Peaks: Intersection

Peak	A	B
Value	10	8

Ability: $average\ value = 9$

Quiz: Which characteristic of teams makes them so effective in solving problems? (a) Expertise, (b) Argument, (c) Diversity, (d) None of the above
Ans: (c) Diversity
Explanation: *What is being explained here - finding different ways to solve problems - is a description of diversity. Keep watching for an extensive explanation.*

Claim: The 'Team' can only get stuck on a solution that's a local optimum for every member of the team. ***Best team*** will have people with different local optima perspectives and diverse heuristics!

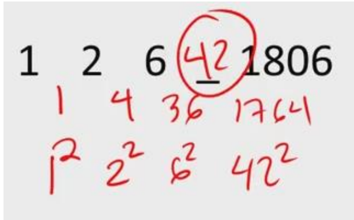
What's Missing:
1. Communication (must be perfect)
2. Error in interpreting the value of a solution (everyone has to value the solution the same)

9.5 – Recombination

Recombination:
- A powerful driver of innovation
- More solutions means more potential for recombined solutions.

Example:
1 2 3 5 _ 13. What's missing?
$n = (n-1)+(n-2) = 8$
1 4 _ 16 25 36 What's missing? $n = k_n^2 = 9$

Example (cont.):
1 2 6 _ 1806 What's missing? 42
Combine sum and square examples. The difference between each set of numbers is squared and then added to the previous number: $n_{k+1} = {n_k}^2 + n_k$

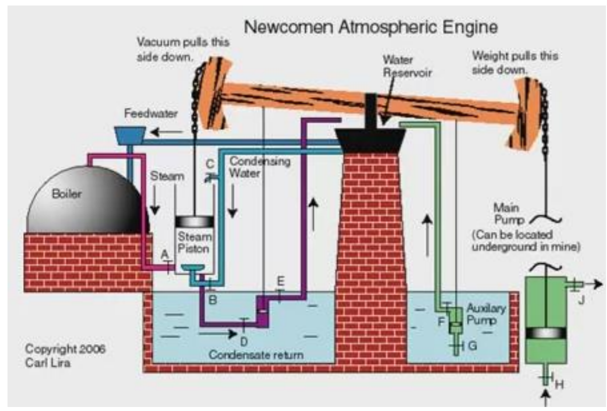


Insight: Combinatorics
How many ways to pick three objects from 10?
$10 * 9 * 8 = 720$
Note: this distinguishes between AFG, AGF, GFA, GAF, FAG, FGA.
When order doesn't matter, divide by the ways to pick the six items: $\frac{10*9*8}{3*2*1} = 120$
Example: Deck of Cards – pick 20 cards
$$\frac{52 * 51 * 50 * 49 * \ldots * 33}{20 * 19 * 18 * \ldots * 2 * 1} = \sim 125\ trillion$$

Recombinant Growth: Martin Weitzman (Harvard.edu)

Exaptation: A solution for one reason applied to another problem.
"Hope is the thing with feathers." Emily Dickenson
Birds: feather evolved to keep warm and then adapted to flying.
Examples: Lasers,
Failed Solutions: Even failed solutions might have application elsewhere. Post It Notes.
Joel Mokyr (northwestern.edu) Gifts of Athena
Rise of university, printing press, scientific ideas foster innovation and exaptation.

Steam Engine: Many parts based on solutions to other solutions



Quiz: Check any inventions that are examples of recombination. (a) Steam engine, (b) Bicycle, (c) Smart phones, (d) Swiss army knife
Ans: (a), (b), (c), (d)
Explanation: *The steam engine uses a combination of pistons, gauges, heat, etc. The bicycle combines gears, wheels, fractions, etc. Smart phones combine phones with applications, a camera, and many other features. The Swiss Army knife features a variety of useful tools. Each of these inventions was, at the time, a "recombination" of existing ideas that created a new, innovative machine.*

Summary:
(1) represent the problem,
(2) people looking for solution,
(3) when solutions are found they can be recombined into new solutions. Use diveristy of heuristics and perspectives to reduce set of 'local' solutions.