1) Nuclear mass

In relativity Einstein showed an equivalence between mass and energy. $E=mc^2$. This relationship is observed experimentally in many ways. Particle and matching antiparticles can annihilate becoming radiation, photons, with energy calculated via $E=mc^2$. Processes that bind systems of particles together and lower the potential energy of the system also lower the mass of the system.

For instance the mass of an atom is:

$$M_Ac^2 = M_Nc^2 + Zm_e c^2 - B_{atomic}$$

where, $B$, is the binding energy of all the electrons and has been defined as a positive number. This can actually be measured using ions.

For the nucleus:

$$M_Nc^2 = Zm_p c^2 + Nm_n c^2 - B_{nuclear}$$

often the mass of the atom is used instead the nucleus mass and the proton mass is replaced with the hydrogen mass. This accounts for the electron mass but neglects the atomic binding energy which is very small.

$$M_Ac^2 = ZM_H c^2 + Nm_n c^2 - B_{nuclear}$$

The binding energies per nucleon are on order 1-9 MeV/nucleon, found to be small for low $A$, increase steeply to $A=16$, peak at $A=56$ (Fe iron), and then fall slowly for $A>56$.

The steep rise indicates that adding more nucleons in increasing the attractive force felt by each additional nucleon. However, then the effect saturates and becomes roughly flat. This is consistent with a short range force where the new nucleons are simply too far from some percentage of the nucleons to feel and additional attraction.
We see from the above plot that the binding energy per nucleon is about 1-9 MeV. In fact this is an underestimate of what it takes to remove a nucleon from the nucleus, especially in the light nuclei. For instance to remove a nucleon from He requires on order 20MeV. Consider 4He:

The binding energy per nucleon for 2H (proton+neutron) is 1: total 2=1+1
For 3He (adding 1 proton) is 2.5 total 7.5: 1+1+5.5
For 4He (adding 1 neutron) is 7 total 28: 1+1+5.5+20.5

This plot has important ramifications for the formation of elements.

The binding energy is contributing negatively to the potential energy. Therefore it is energetically favorable for nuclei with low A to fuse into atoms with high A. Though there has to be a compressing force sufficient to overcome the proton repulsion force and bring the nuclei into close enough proximity to feel the nuclear attraction. For instance, this can happen in the heart of the sun.

For very large nuclei, well above Fe, it can be energetically favorable to divide. Thus fission. Though in this case the potential energy gain from fissioning has to be bigger than the energy potential barrier that nucleons are confined by. This is true for a relatively small set of very large atoms. Also it is possible to force nuclei together to
form very large nuclei but this takes an even stronger compressing force. For instance, this can happen in the compressing force at the center of a supernova. This makes the atoms larger than Fe relatively rare.

2) Nuclear (strong) force

Detailed Information can be extracted on the potential by performing scattering experiments with nucleons energetic enough to approach the nucleus closely.

A fairly exact form of the potential can only be well understood for the simplest system, the deuteron, 2H, with one proton and one neutron.

Important qualitative details can be understood from the deuteron. I discuss them here with numbers that are representative of the typical nucleus in a larger atom.

The nuclear force is attractive and significantly stronger than the any electrostatic attraction at 1.0fm (max typically at 0.9fm). It rapidly diminishes as is negligible at distances beyond 2.5fm. Between protons and neutrons or neutrons and neutrons there is a dipole attraction that is stronger at distances beyond 2.5fm. For protons and protons there is an electrostatic repulsion that is stronger at distances beyond 1.7fm. There is a magnetic repulsive force (largest between spin aligned nucleons) which becomes larger at less than 0.7 fm.

An exact understanding of a multi body (greater than 2) nucleon is not possible. However, above details can be used to build a simple approximate model of the nuclear potential.

All this detail can be well approximated by a finite square well about 2.0fm wide and 40 MeV deep. The proton-proton potential well is different because of the strong repulsive
force beyond the range of the strong force. The strong force between the any pair of nucleons is found to be identical and the full potential well is only different because of electromagnetic forces. Note the potential barrier for protons, which is significant, and makes the fusion process difficult.

In a multi-nucleon system you place many of these potential wells adjacent to each other. An individual nucleon should see an approximately continuous potential well, within the size of the nucleus. The nucleons in this system do not interact with each other. To interact they would have to collide and exchange kinetic energy. However, if they are fermions and all the energy states of the system are occupied then there is no way by colliding that both nucleons could occupy allowed energy states of the system. This quantum phenomenon makes the probability of interaction zero. Note that nucleons in an outer orbit or in a excited states can collide and exchange energy since there are possible quantum states they could occupy. Also the lowest energy state is not necessarily -40MeV. It can be calculated approximately using an approach like the finite potential well.

This picture is consistent with the various observations of the nuclei.

a) The size: The size indicates a constant value of separation between nucleons.
b) The binding energy: This indicates that only a finite number nucleons interact with any given nucleon numerically giving a ~2.5fm range force.